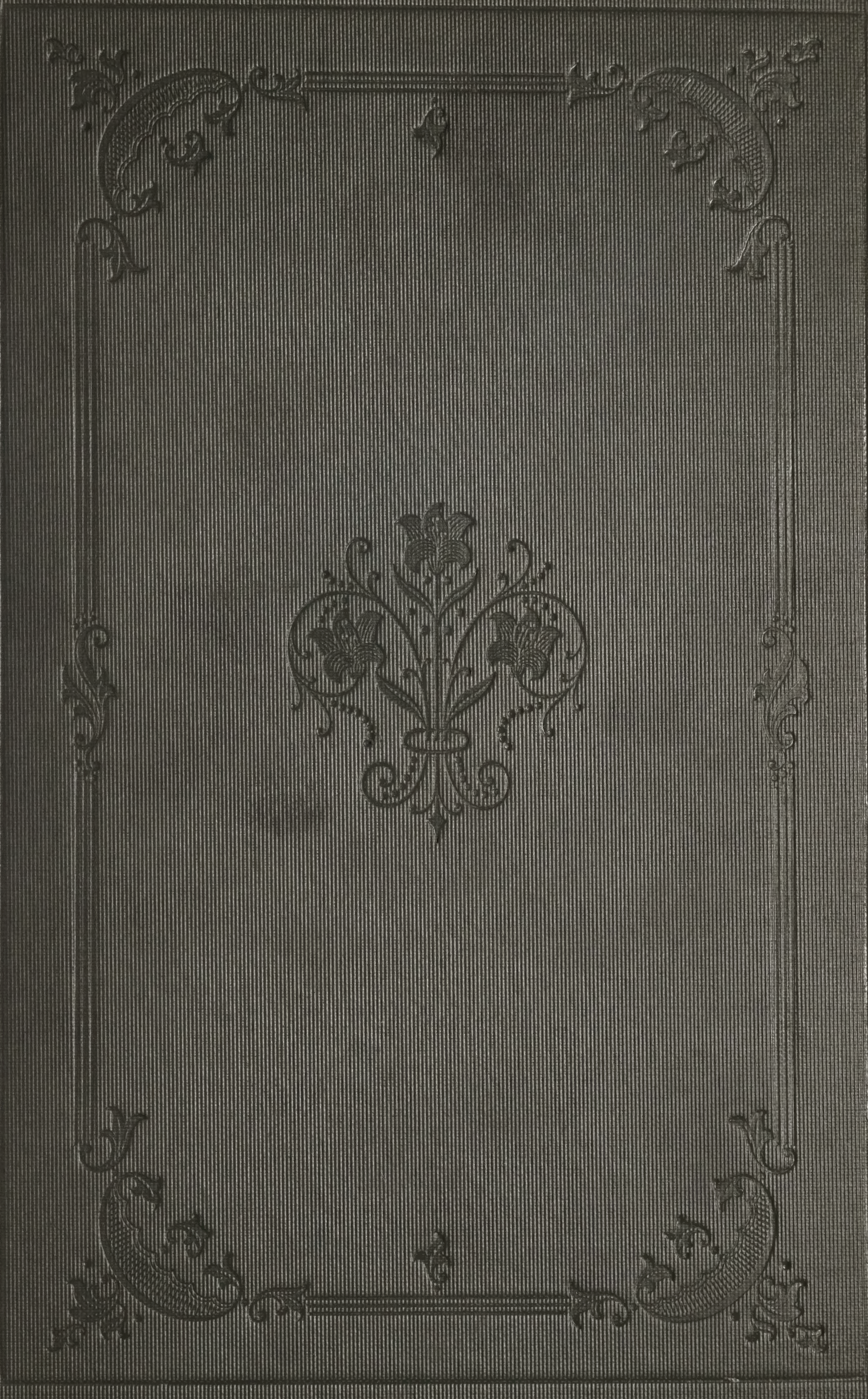

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THE WONDERFUL UNIVERSE.

"Is not God's Universe a Symbol of the Godlike; is not Immensity a Temple; is not man's history, and men's history, a perpetual Evangel? Listen, and for Organ-music thou wilt ever as of old, hear the Morning-Stars sing together."

—*Carlyle.*

"O how loud
It calls devotion! genuine growth of might!
Devotion! daughter of astronomy!
An undevout astronomer is mad."

—*Young, Night Thoughts.*

"The spacious firmament on high
With all the blue ethereal sky,
And spangled heavens, a shining frame,
Their great original proclaim."

—*Addison.*

"The heavens declare the glory of God; and the firmament showeth his handiwork."

—*Psalms.*

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INTRODUCTION.

EVERYTHING in the world is interesting. Every hill, every stone, has a story to tell you if you have only learned to look for it and to understand it. All around you the story is written,—in the rocks, in the mountains, in the rivers—, the wonderful story of what was happening long ago, and of how even now our world is always changing, until some day it will be very different from the world we know. If you learn to see how interesting all the things around you are, all the rest of your life will be more full of a pleasure that no one can ever take from you.

The life of our world! What a varied and wonderful life it has been! There was a time when the land around you was all at the bottom of a great, warm sea. There was a time when, all the year around, it was very hot and wet; when all our country was marshy, and great tall trees like ferns were growing everywhere. Then came terrible reptiles, almost as large as houses, which crept over the land and swam in the water, and strange, savage creatures, of enormous size, which flew back and forth in the air, killing and devouring all the living animals they could catch. Truly, if we could have been on the earth then we would not have found it a very safe or pleasant place to live. And as the years went on, these great creatures died off, one after another; the trees and other growing things took on new shapes; mountains and valleys were slowly formed, and at last the earth grew to be the world on which we find ourselves today.

We know that all these, and many other strange things once happened, just as surely as if we could have seen them. For as our world grows the traces of its past life are everywhere left for us to read. And the things that are happening now are no less interesting. We see the rain washing millions of tons of earth into the rivers, which then carry it down to build new countries in the sea. In some places the land along the seashore is rising, and towns to which ships used to sail are now far back from the beach, while in others the land is steadily sinking under the water. And all the time, the little coral insects are steadily building away, raising new countries from under the ocean.

We can read about these things in books, but it is ever so much more important for us to learn to see for ourselves the interesting things that are around us. If we take a walk into the country, every little rivulet is of interest to us, for we know that it is slowly wearing the hills away; a bed of gravel may tell us how it was once at the bend of a river, or perhaps at the foot of a great, flowing mass of ice; and we will know that every flat rock was once nothing but soft mud at the bottom of some still water, which for ages and ages slowly grew harder, and at last, after a great many things had happened to it, found itself on top of the ground where we may pick it up. Even in the crowded city, we may stop beside some building and notice how its stones are filled with little rounded pebbles. And we may think to ourselves how once the pebbles lay upon a seashore; how they were smoothed, year after year, by the washing of the waves, and how at last they sank below the water and slowly became a part of a solid rock.

There is a story of a great man who, because he was not well, was told to take a sea trip among the beautiful islands of the Mediterranean. But all day long he sat in his cabin, reading or resting. Of all the beautiful and wonderful things around him he did not see one. Wherever such a man may go, he is always in prison. Thousands of most interesting things are around him on every side, but he does not know it, because he has never learned to look for them. But how different it all is to one who has learned to see! To him the world is a beautiful place; he meets with a hundred things which interest him every day. As long as he lives he is finding out more, and what he has learned makes his whole life a pleasure.

Our world is not the only world there is. The whole sky is filled with the bright little lights called stars, and men have found out that every one of them is much larger than our earth is. And there are the great Sun, and the round Moon: what kind of bodies are they, why do they look so bright, and what would we find on them if we could visit them? Is it possible that there are other worlds like ours anywhere? If men have found and studied other worlds, how did they find them, and what do they look like?

Interesting as the story of our own earth is, the thousands of worlds which are around us are still more wonderful. Have you never wondered how the things which you see in the sky are kept up there?

Have you wondered how far away they are, how big they are, and what they are like? We can tell you these things, and we can tell you about many other wonderful things, out among the other worlds, of which you have probably never heard.

Perhaps some day when you have learned more about these wonderful things you may grow so interested in them that you will be an astronomer, and spend all your life looking at them and trying to find out more about them. There are many men and women who are doing this. Or perhaps you may find that the study of our own earth is more interesting to you than anything else, and you may grow to be a man called a geologist. But whatever you are when you grow up, you will enjoy yourself more and be a much happier man or woman if you have learned to understand the interesting things which are around you.

In this book we will tell you first about all the great worlds and suns which are around us, and next we will tell of what has been happening on our own earth during the long ages that are past.

In the preparation of this volume many eminent contributors, all of whom are well known in the world of science, have taken part. Each in his own field has notably advanced our knowledge of the universe about us; Doctor Turner, by his researches on the long period disturbances produced in the motion of one planet by another; Doctor Furness, by her measures of comets and asteroids, and by her determination of the positions of the Polar Stars; Doctor Barton, by his researches upon the paths of asteroids; Professor Apple, by his careful observations and drawings of the major planets; Doctor See, not only as an observing astronomer by his discovery of many new stellar systems and his accurate measures of satellites, but also, in the theoretical field, by his numerous profound researches into the development of suns and worlds, and Doctor Moulton, whose epoch making work in Cosmogony is well known to every astronomer.

It is with no little pride that we lay before the reader this result of the labors of such eminent scientists. Each contributor has done his part with the utmost care, accuracy, and thoroughness. Each is in hearty sympathy with the design of this unique library,—a design to awaken in young people a perception of the many wonderful things about them and to supply them with a reliable account of these things in an attractive form. Each has most carefully prepared his part and has embodied our very latest knowledge and discoveries in the account of his chosen field. And to each of these eminent contributors, for his enthusiasm in this work and for his cordial coöperation, the Editor-in-Chief desires to express his most sincere and hearty thanks.

ERIC DOOLITTLE.

PART I.

THE WONDERFUL UNIVERSE.

CHAPTER I.

What We See in the Sky at Night.

WHERE WORLDS AND SUNS ARE SEEN.

LET us go out of doors some dark, clear night and look up at the wonderful heavens. What a beautiful sight it is! There is the great, round sky above us all covered with hundreds and thousands of those bright little lights called stars, which shine out hour after hour and year after year without once growing dim or going out. Indeed, all our whole lives long we will see the same beautiful stars shining steadily down upon us; in some parts of the sky there are so many and they are so bright that we turn to look at them at once; in other parts there are fewer or fainter stars and these parts seems darker, while in one place there are such a great many little stars packed so closely together that they seem to make a beautiful, golden pathway all across the whole face of the heavens.

Have you ever looked at these beautiful stars? Have you ever seen how some are bright and some are faint, and how they are even of different colors so that some look reddish and many look yellow and still others are blue? And have you ever wondered what they are; how big and how far away they are, and how they were made, and what they are made of? Very many of these things men have found out. And they have found out many other wonderful and surprising things about the bodies so far away from us in the sky. For there are very many things there beside the stars, which are just as interesting and wonderful as the stars are.

We will try and tell you about all of these things in this book. About great worlds like our own world, which men have seen but which they can never visit; about other worlds on which we could not live because they are cold and dead; about great suns, far larger and hotter than our own sun, and bright, shining clouds out of which the suns are being made. Is it not interesting to learn of these things which are around us? Is it not wonderful to think of how there is a marvellous universe of worlds and suns of which even our whole earth is only a little part? And that which will be of the greatest help to us is this, that from the study of this wonderful universe we will be drawn nearer to an understanding of its Creator, who has made and who governs it all.

LEARNING THE STARS.

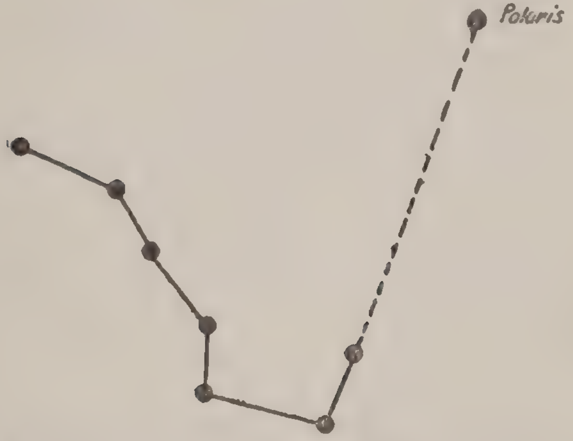
As soon as we look at the sky we see that the bright stars are not scattered evenly over it, but instead of this are gathered into many very bright and striking groups. From the time when the very first men on the world saw this they gave names to these bright groups, and they named many of the single stars too. Many of the groups and stars were named by people who lived so long ago that we do not know anything about them at all. The very oldest nations that our histories tell us about lived long after these earlier people. Many of our star names come from the Arabs, who wandered over the desert thousands of years ago; others come from the old, old nation of Babylonia, and still others were named by the ancient Greeks. But even many of these names, old as they are, were not first used by these people; they learned them from some still earlier people or nations of whom we know nothing, who lived on the earth and passed away and are altogether forgotten.

In some parts of the sky there are long, winding rows of stars which were called by such names as the Dragon, the River, the Serpent, and the Water Snake. In others there are brighter, more striking groups which were given the names of men and animals, but the figures which these stars make do not usually look at all like the animals for which they are named. If you wish to look in the sky for the Bull, or for the Eagle, you will find that the groups which are called by these names do not look in the least like a bull or an eagle. The last was perhaps so named because when in summer the sun was highest in the heavens it drew nearest to this bright group, and so the group was called after the bird which flies the highest of all birds. And the Bull was named seven thousand years ago, when the only civilized people were those in a little part of the earth around Arabia and all the rest of the world was filled with savages. But why they called the group a Bull we do not know.

It is very interesting to learn to know all these bright groups of stars and to be able to call the brighter stars by name. We will learn later that the stars which we see in the sky in winter are different from those which we see in summer. As the months go by, it is a great pleasure to welcome them on their return as they enter the evening sky one after another, and the more we have learned about each of them the greater our pleasure in looking at them will be.

THE GREAT DIPPER.

There is one beautiful star group which everybody should know. It is easier to find than many others because on any clear night, winter or summer, it may always be seen shining out in nearly the same part of the sky. If you will go out of doors about eight o'clock on any clear evening and look toward the north, you will see seven bright stars which lie in such a way that if you think that there are little straight lines drawn so as join them together then the straight lines will make a picture of a large dipper on the sky. Four of the stars make the bowl and the other three make the handle of the dipper, but the handle seems bent at the star which is next to its end. This large bright figure is called the Great Dipper. All of the seven bright stars and many other fainter ones near them have been called the Great Bear for many thousands of years. The Great Dipper is only a little part of the Great Bear.



Showing the shape of the Great Dipper, and how a line drawn through its first two stars nearly meets the North Star.

If the evening when you are looking at the stars is one of the cold evenings of January, you will see the Great Dipper stretching straight up from the ground, just as if it were being balanced on the end of its handle. In April you will see it high up in the sky, almost straight overhead; in July it is again near the ground, but now it looks as if it were being balanced on the front edge of its bowl, and finally, by October, you will see it resting right side up, very near the ground in the north, in just the right position to be filled with water. All this time the shape of the dipper does not change at all; the seven stars always form exactly the same picture, but the whole figure changes its position in the sky.

When you have learned these seven bright stars you will always know them whenever you look at the sky. All your life long you will see them shining out in the north: and there they have been since long before the pyramids were built, or history began, or the first men appeared on our earth. Job sang of them four thousand years ago,* and if we look at them tonight we see them just as he saw them. Age after age, while nation was following nation on the earth, the same beautiful stars were shining out in the sky.

A great many years ago many of the people in Asia called these seven stars a bear, and when white men came to America they found that the Indians called them a bear, too. Men have long wondered where the first Indians of America came from. Perhaps this shows that they came from Asia long ago; but we are not sure, because the Indians may have just happened to call the group a bear, although it does not look at all like one. In India the stars were called the Seven Bulls, and in China the Bushel.

Before we leave this interesting group let us look at the star just at the bend of the handle. If you look carefully you will see that very near this there is a very faint, bluish, little star, and this small object has been spoken and written about by the people of all countries. The Arabs called it the Lost, or Neglected One, because it is so hard to see; but the Germans call it the Rider who sits upon the bright star or Horse below him, and drives around and around the heavens forever.

HOW TO TELL WHICH WAY NORTH IS.

Perhaps some day you may be in a country which you do not know, or you may be out on the sea or in the woods, and you may be lost. You may go very far in different directions hoping to find your way, and at last you may get so confused that you do not know at all in what direction anything is. Travellers and hunters usually find their way with a compass, which is a little round box with a needle in it that always points toward the north, but one who knows how can find his way by the stars, just as the earlier people and the Indians used to do.

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* Job ix, 9, and xxxviii, 32. Revised version.

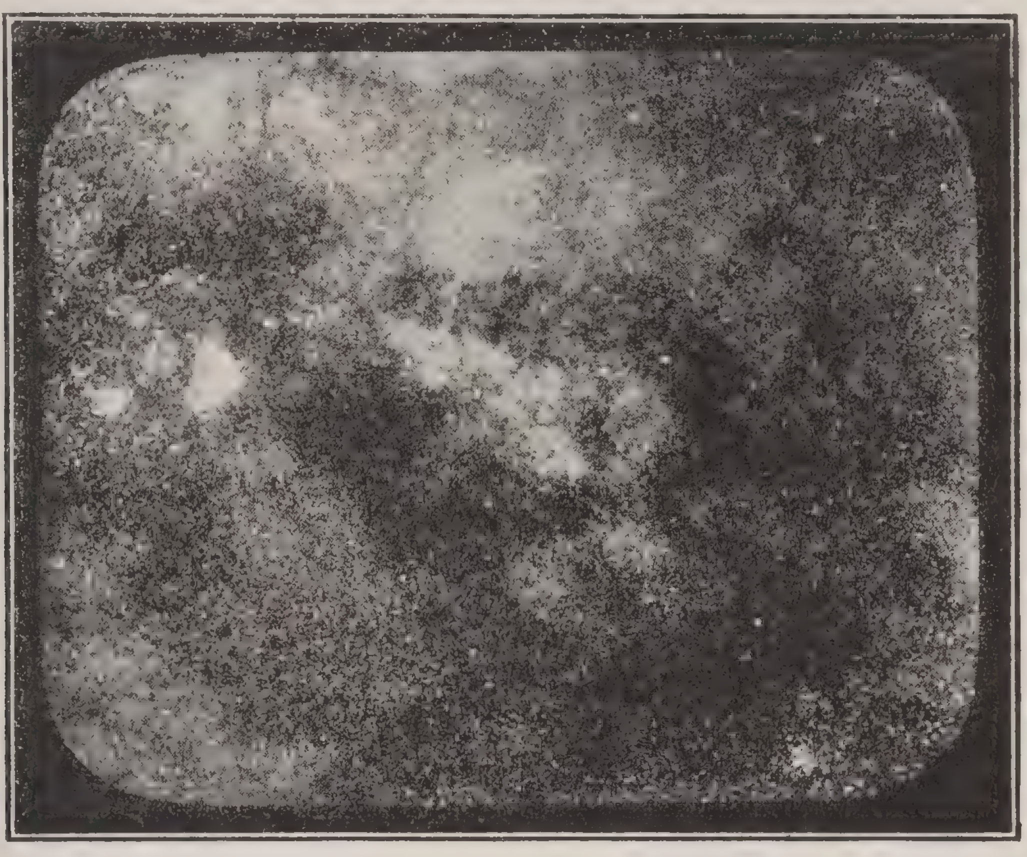
The two stars which make the front edge of the bowl of the Dipper are called the Pointers, because they point almost exactly to a star named Polaris, or the North Star. If you look at these pointers in the sky and think of a line drawn through them so long that it is nearly as long as the dipper itself, you will see that the end of the line is at a rather faint, yellowish star, and this star is the North Star itself. No matter in what position the Great Dipper is, if we follow along the line made by the two pointers, we will come to the North Star, and as there is no other star nearly so bright as this one in this part of the sky we can easily find it.

Now, wherever you may be on the earth, this North Star will be just north of you. If you turn your face toward the star and hold your two arms straight out from your body, your right hand will point east and your left hand west, and south will be exactly behind you. If you were lost in a woods which you knew were east of where there were open fields and houses then you would walk to where you left hand was pointing, and in time you would get out of the woods. Every little while you should stop and face the North Star again and stretch out your arms to be sure that you were still walking in the right direction. If you knew that there were houses east of the woods, you would walk to where your right hand was pointing; if they were north of the woods you would walk straight toward the North Star, and if they were south you would walk away from it. Even if you did not know at all in what direction you should go, you could keep always walking east or north and at last come to help, instead of walking around and around in a circle as lost people so often do.

We will see that the stars of the sky move over the heavens and that most of them rise and set, just as the sun and moon do. But the North Star stays all night long in almost exactly the same place. It was called by early people the Fixed Star, the Ever Visible, and by the Arabians, the Star of the North. The Chinese call it the Imperial Ruler of Heaven, while to the astronomers of today it is known as Polaris.

THE MILKY WAY.

There is a wonderful band or girdle of stars passing all the way around the sky which is called the Milky Way. If we look at it without a telescope it seems to be a beautiful golden strip, very bright in some places, broken up into separate parts in others, and in still others very much spread out and very faint. But even with a pair of opera glasses we see that it is a great cloud of thousands and millions of stars packed closely together. And if we look at part of it with a large telescope or take a photograph of it, what a wonderful sight do we see! It is all a wilderness of brightly shining stars. Here they are heaped up into great cloud forms, and each great



Photograph of a Part of the Milky Way, showing hundreds of thousands of stars, heaped together in great star clouds.

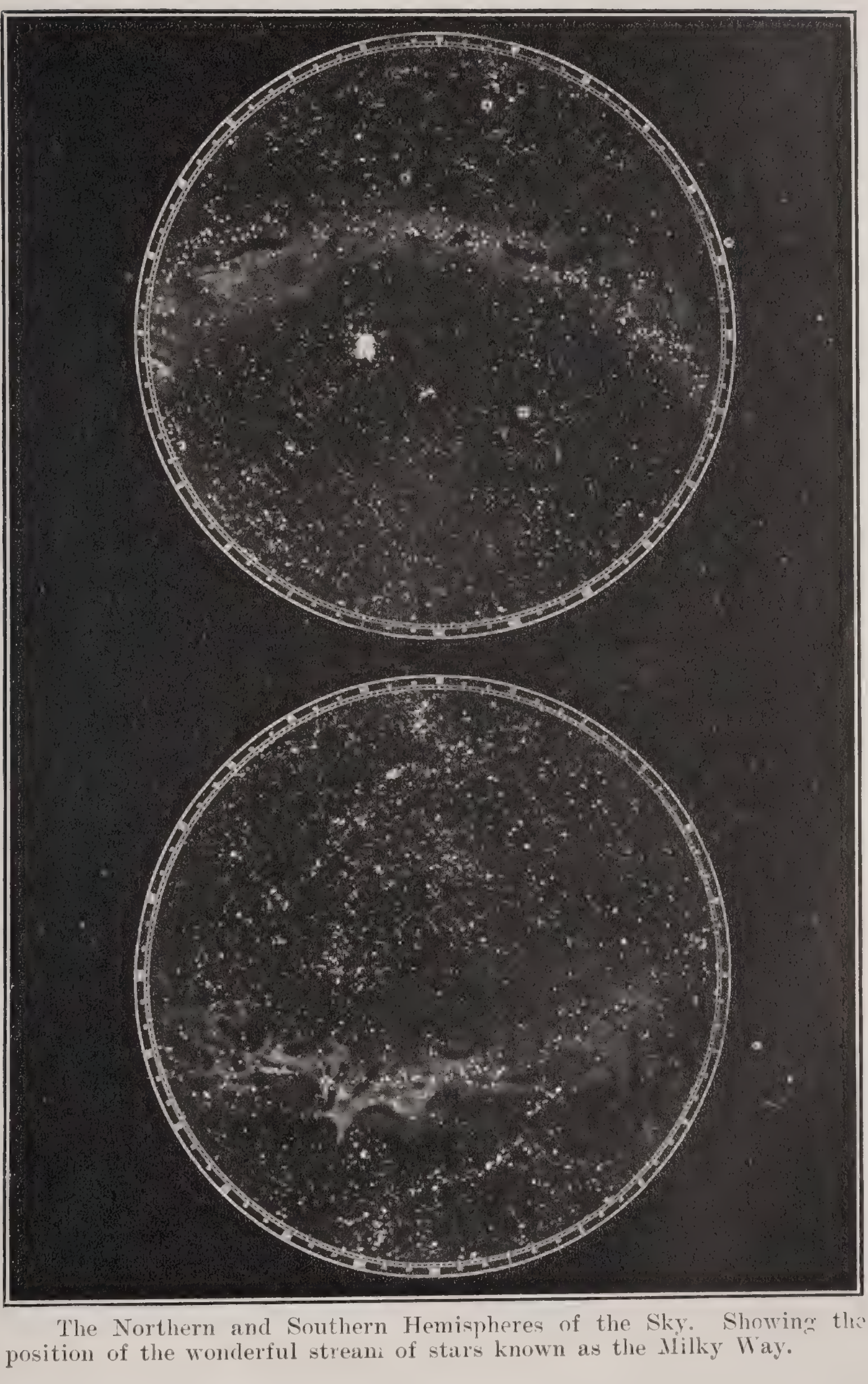
cloud is made of thousands and thousands of stars; there they are crowded into dense star clusters, and in other places there are long black lanes stretching through the mass of stars as if some great body had pushed among them and brushed them away. More than one million stars have been counted on a photograph of one little part of the Milky Way.

On any dark January evening we may see this beautiful golden arch passing from the ground in the southeast right up through the very highest point of the heavens, and finally meeting the ground again in the northwest. The southern part is bright and wide; overhead it is even brighter, but it is here very narrow, and as it draws near the ground in the north it becomes much wider and fainter.

This is the part of the wonderful ring of stars which we see in winter, but the part which is in the sky in summer is even more remarkable. The south part is then even more wonderfully broken up into great knots and clouds of stars: there are long branches and patches which seem to be breaking away from the main stream, and there are great dark places where the stars are very few. It is as if there are great forces at work here, heaping the stars together in some places and drawing them apart in others.

To see the Milky Way clearly the reader should choose a night when there is no moon in the sky. It will then shine out brightly and he will find that all parts of it are full of star clouds and clusters and wonderful objects of interest. During the months of April, May and June, however, it is so near the ground in the sky that it cannot be seen well in the early evening.

The Arabs called this band of light the River of Sparkling Dust; the Indians and the little Bushmen of Africa called it a pathway of hot and glowing ashes; while the Patagonians think it is a broad, heavenly road on which their dead friends are hunting ostriches.



The Northern and Southern Hemispheres of the Sky. Showing the position of the wonderful stream of stars known as the Milky Way.

HOW THE SKY SEEMS TO BE ALWAYS TURNING.

Everyone knows how the sun and moon rise in the east and move slowly over the sky and set in the west. And if we go out of doors and look toward the south on any clear night we will find that all of the stars which we see are moving over the heavens just as the sun and moon do. One group after another moves up from the ground in the east, and climbs higher in the sky, and at last sinks toward the ground in the west. And so beautiful star groups are setting in the west and others are rising in the east all night long.

It is very important indeed to notice that the shapes of the star groups never change and that they do not change their places among each other. They are all moved together, exactly as if they were fastened on the inside of a great hollow ball, and as if this great ball turned slowly around from east to west and carried all the stars with it. Very many years ago people thought that there was really a great crystal sphere, or ball, there, that all the stars were fastened to this sphere, and that we are inside of the sphere, exactly at the center of it. They thought that it was because the sphere was slowly turning around that the stars rose and set. And they thought that outside of the sphere there was a region of fire, and that outside of this there was heaven.

We know now that the sky is not really a round sphere as it seems to be, and that the stars are not all at the same distance away from us. They really form a great cloud which stretches wonderfully far away from us in every direction and the more distant stars of the cloud are thousands of times farther away from us than the others are. Our earth is inside of this great cloud. In whatever direction we look we see its stars filling the sky at night, but even the nearest of them are so far away from us that we cannot judge by looking at them whether they are farther away than the others or not. All seem to us to be equally far away and so they look to us like a great round ball of stars.

Hour after hour, all night long, the great round sky seems to be slowly turning. One star group after another rises in the east, until at last the slowly turning sphere brings that part of the sky in which the sun is above the ground and then the stars disappear. But the sky is really all covered with stars in the daytime just as it is at night. It is only because our sun is so over-poweringly bright that we cannot see them. They are really there in the sky all day long, and we can see and measure the brighter ones with a telescope in the daytime just the same as at night.

WHY THE STARS WE SEE IN WINTER ARE DIFFERENT FROM THOSE WE SEE IN SUMMER.

All around our earth there is a great cloud formed of millions of stars which stretches away from us in every direction. We ourselves are in this cloud and we see the stars at night because we are then looking right into and through the cloud which is around us. But we can only see one half of all the stars, because the rest of them are hidden by the ground on which we stand. If our earth could suddenly be made transparent like glass, so that we could see through it, we would see the stars all around us, below our feet as well as above our head. We would see ourselves standing on a round world which would seem to be at the center of a wonderfully large round sky, and this sky would be all covered with stars.

If the sun could be made much dimmer so that we could see the sky around it all filled with stars in the daytime, we would see that the sun is steadily changing its place among them. If we saw it in the middle of one group today, then by watching it for a few days we would see that it was very slowly moving across this group towards the east, and in a week or two it would have moved away from the group altogether. And if we could keep on watching the sun in this way we would find that it moved all the way around the sky among the stars in just one year.

The sun is so very bright that we can not see any stars when they are very near it. For instance, in summer it moves among the stars which form the group called the Bull, and then these stars rise when the sun does and remain above the ground only during the daytime so that we cannot see them. But by winter the sun has moved all the way around the sky to just the opposite side of it from where this group is and then we see it shining out in the sky in the night time. And so the sun moves around and around the heavens once each year, blotting out by its great brilliance one group of stars after another as it draws near them. The bright stars which we see on any evening are those which are not very near the sun, but in a few months the sun, as it moves eastward, will reach the part of the sky where they are and then it will be other stars, which lie still farther around the heavens and which the sun has not yet reached, that will shine above us in the early evening.

It is most interesting to watch this slow alteration of the face of the heavens as the months of the year go on. The stars seen in winter are the brightest of all, and yet we are always glad when we see the first of the delicate spring groups, which tell us that the transformation of the winter into the summer sky is beginning.

CHAPTER II.

The Great Star Cloud which Forms Our Universe.

WHAT THE STARS ARE.

LET us now try to see more clearly what this wonderful universe of stars that surrounds us is like. Let us think of a great cloud of dust, such as we often see blown high in the air on a dry summer day: perhaps this dust cloud, although so very little a thing, may help us to understand more about the wonderful star cloud so inconceivably much larger.

If you stand a little distance away from it, the cloud of dust may look like a great, rolling, yellowish mass, and it may even seem to be solid, especially if there is very much dust in it indeed. But if you walk inside of the cloud you see at once that it is not a solid mass at all; it is made out of thousands and thousands of very little grains of dust, some moving one way and some another. In whatever direction you look you will see the cloud all around you, but it looks much thicker or more solid in some parts than in others, either because there are more particles of dust in those parts or because you are looking through a greater thickness of the cloud.

It is in just the same way that we see the wonderful cloud of stars around us. It is like the cloud of dust, but instead of being made out of little fine dust particles, so small that we can hardly see them, it is made out of shining stars. Each bright star is like a grain of dust, and we must think of ourselves, and our whole earth too, as being smaller than almost the smallest grain of dust of all. We are inside of the cloud; in some places, as where the Milky Way is shining, it seems thicker than in others, and by carefully studying it in every direction we are able to find out a good deal about what its real shape is.

What is each one of these bright stars, and how can they all keep shining through age after age as they do? It was a very long time before men found this out. Even in the very largest telescopes every star looks only like a brilliant little point of light; we cannot see what there is on them or what their shapes are as we could do if we were looking at the sun or at the moon. But in a very wonderful way which we will soon tell about, men learned how to find just what the stars are made of. And they have learned how far away and how hot many of them are, and even to find out just how much they weigh. It is truly a wonderful thing that we can learn all this, and yet we will see that there is still very much that we do not know.

In another part of this book we will tell about our sun and show how it is a wonderfully large and wonderfully hot body; so large that more than a million earths like ours would have to be piled together to make one sun, and so hot that if any rocks or metals were put near it they would be melted and even turned into a glowing gas by its heat. And the stars of the sky are suns: they are wonderfully large, hot worlds, just as our sun is. Some of them are even thousands of times hotter and brighter than our sun, and they only seem less bright to us because they are so very much farther away.

We see that the universe of stars like a cloud of dust, but that each dust particle is a star and each star is a great, hot, glowing sun. We, on our little earth, are very near one of these little particles; indeed our world is forever moving around and around it, and as this particle is so very much nearer to us than any of the others it seems to us to be very much hotter and brighter than they are. The little particle which is so near us is our sun. But it is not really larger and brighter than the other suns. It is only one of the millions of stars of the great cloud and it is a smaller star than most of the others are.

HOW FAR AWAY THE STARS ARE.

Even the earliest astronomers knew that the stars are farther away than the clouds, because the clouds often pass in front of them. And they knew, too, that they are farther away than the moon for just the same reason; if we watch the moon moving over the sky we often see it passing between us and some of the stars and hiding them from our view. But it was a very long time before they found out how wonderfully far away even the very nearest of the stars really are.

We have all noticed that when we are riding in a railroad train those things which are near us seem to be rushing past us very much faster than those which are far away. A telegraph pole or a signal very near the track will flash past the window so quickly that we can hardly see it, but if we look at a tree or a hill which is very far away we hardly notice that it is moving at all.

Now all the time, day and night, we are flying along very much faster than the fastest railroad train. Our earth is moving around and around the sun more than eighteen miles each second, and all the people and houses are always being carried with it on its journey. Though the world is going so very fast yet it moves so smoothly and steadily that we never feel that we are in motion at all. But if we are really traveling so fast ought we not to see the stars seem to move, just as the trees and houses seem to move when we look at them from the window of a train? After six months of our earth-journey we are one hundred and eighty-six million miles away from the place where we were six months before; surely, if the stars are not inconceivably far away we will see them move, at least a little, while we are going one hundred and eighty-six millions of miles.

By using the very finest telescopes and by measuring with the very greatest care, astronomers do find that some of the stars seem to move while we are making this long journey. But even the nearest stars move very little indeed, and nearly all of the stars are so wonderfully far away that we can not find that they have moved at all. If we measure very carefully with our telescopes just how much a star seems to move we can tell how far away it is; if another star seems to move half as much as the first one we know that it is just twice as far distant, but if we cannot see that a star has moved at all we only know that it is wonderfully far away, too far from us to measure, and we cannot tell at all what the distance to it may be.

The distance to the star of the great cloud which is nearest to us of all is more than twenty-five thousand million million miles. We can not possibly understand so stupendous a number as this, but let us try to form some idea of how large it is. If we should ride toward this star so fast as a mile a minute, we would require fifty-six million years for the journey; a cannon ball, if it could keep moving as fast as when it was first shot out of the cannon, would require one and one-half million years. To show, in another way, how great this number is, suppose we look at a watch which ticks five times each second, or 432,000 times in a day; this is two or three times as fast as we can count. In seven months it would tick as many times as there are miles in the distance from the earth to the sun, but it would require one hundred and sixty thousand years to tick as many times as there are miles between us and the nearest star. If one person who represents the earth should stand eighteen feet away from another who represents the sun, and if a third person wished to represent the nearest star, then he should stand nine hundred miles away from the other two, that is, as far away as St. Louis is from New York.

If the sun could be placed where the nearest star is it would look less bright to us than that star does. Some of the stars seen with the telescope must be a thousand or more times as far away as this nearest star and if our sun could be placed where they are we could not see it at all. We can not usually find how large the stars are, because they always look like points and never appear round as the sun does. This is because they are so very far away. If our sun were as far distant as the bright star Sirius it would look no larger than a five-cent piece held up two thousand miles away from us.

"LIGHT YEARS."

Nearly two hundred and forty years ago it was discovered that light requires a certain very small time to pass from one place to another. If a gun were fired off eighteen miles away from you, you would not see the flash at quite the time when it occurred, but a very little time later. In fact, the light of the flash would travel eighteen miles in one one-thousandth of a second, and so you would see the light just one-thousandth of a second after it first flashed out. It would not be until one minute and twenty-seven seconds later that you would hear the noise of the explosion, for sound moves very much more slowly than light does, and so it would not reach you so soon.

As the speed at which light moves is so very great we never need to take it into account when we are observing lights on the earth. For in one second it moves one hundred eighty-six thousand three hundred and thirty miles, and this is so fast that in one second a beam of light would travel all the way around the earth more than eight times. But the heavenly bodies are so far away that it is often important to know how long the light which comes from them has been upon its way to us. For when we look at any body in the sky we do not see it just as it is at the instant we are looking, but as it was when the light came from it. Thus light requires eight minutes to come from the sun to us, so whenever we look at the sun we see it as it was eight minutes before. The moon is so much nearer than the sun that its light requires only one and one-third seconds to come to us.

The nearest star is so very far away that its light, even though it travels more than one hundred and eighty-six thousand miles in each second, spends more than four years in making its long journey to our earth. If anything remarkable should happen on this star, or if it should suddenly grow dark, we would not receive the news until four years later. And if there could be astronomers there with telescopes so large that they could watch what was happening on our earth, they would see everything just as it occurred and in its proper order, but while they were watching any event they would know that it had really happened and been finished four years before they saw it.

Astronomers find in this very rapid motion of light a convenient way of telling the distances of the stars. They say that the nearest star is 4.3 Light Years away, which means that its light requires 4.3 years to come to us. Many of the stars are known to be ten, twenty, or even thirty light years away, but if a star is farther away than thirty light years it does not seem to move as we view it from our moving earth and we cannot tell at all how far away it is. It may help us to understand something of the inconceivable size of the great star cloud to say that the average distance between any two of its little stars, even when these seem almost to touch one another, is believed to be about ten light years, and that the distance through it is very probably three or four thousand light years, and perhaps much more.

HOW THE STARS ARE MOVING.

In early times astronomers believed that except for their daily rising and setting all of the stars were motionless. At first they thought that they were all fastened to a great sphere which turned around once each day, but even when they learned that this could not possibly be true they could not see that the stars were moving among one another at all. If three bright stars were seen in a straight line, as there are in the beautiful group called Orion, or if many stars formed a figure like a dipper, the three stars would stay in a straight line year after year, and no matter how long they waited the shape of the dipper never seemed to change. Maps of the star groups which were made two thousand years ago have all the groups marked on them, and these look as if they had been made today. If any of the stars had moved very far over the sky this could not be so; the shapes of the groups would keep changing from year to year. Because they never seemed to move among each other, the ancients called the stars which form the star groups of the heavens the "Fixed Stars."

But in late years, when telescopes have been made so very powerful, and when such very small things can be seen and measured with them, it has been found that the "fixed stars" are not fixed at all. All the stars of the sky are rushing along through space, some in one direction and some in another, just as bees in a swarm may be seen to be moving in every way. Some of these enormous suns are moving faster than one hundred miles in each second and many of them move from twenty to thirty miles a second. None of the suns in our great star cloud are at rest; they are drifting in all directions at speeds so very much higher than any motions we ever see on our earth that we can not understand them. And yet all the stars are so very far apart that there is no danger that any two of them will ever run into each other.

If all these suns are really moving so wonderfully fast in all directions, why is it that we do not see them move? As we stand looking at the beautiful reddish, summer star Arcturus, we can think of how it is ever speeding along, more than two hundred miles each second; if we watch it for only one minute it will have moved the enormous distance of twelve thousand miles away from where it was at first. And yet we can not see that it has moved at all. If we should watch it with our eyes or with a small telescope for months or even years we would see it always shining out motionless from exactly the same place among the stars.

It is only because all the stars are so wonderfully far away from us that they do not seem to us to be moving. And yet by carefully measuring their exact places in the sky with very accurate telescopes, we find that as the years go on they really do move, although their motion seems to us to be very slow. On the whole the brighter stars move more than the fainter ones, but this is only because they are nearer to us. There are not more than thirteen stars in the whole sky which have been found to be moving enough to carry them so far as from one of the pointers of the Great Dipper to the other in ten thousand years; nearly all of the stars seem to move so slowly that we could not see them change their positions by even this small amount in one hundred thousand years.

Although these motions seem so very slow yet we know that because of them the face of the sky is always steadily changing. Hundreds or even thousands of years make so little difference that it is hardly noticed, but if we could come back to the earth five hundred thousand years from now we would find that all had been changed. The bright stars would in that time have wandered to all different parts of the sky; the seven stars of the dipper would not form a figure at all like a dipper then, and in the whole heavens we would hardly see a single group which would look familiar to us.

STAR STREAMS, AND THE RUN-AWAY STAR.

We can not only see that the stars are moving over the sky by carefully watching them and measuring them with a telescope, but with a wonderful instrument called a spectroscope, which we will tell about later, we can find out exactly how fast any star is approaching or drawing away from us. The star may be so far distant that even if we should watch it for centuries we could not see that it had changed its position in the sky at all, even when measured with the best telescope, and yet by observing it for only a few hours with a spectroscope we can find whether it is moving toward us or away from us and just how rapidly its distance is changing. It is found, for example, that the North Star is sixteen miles nearer us at the end of each second than it was when the second began.

When we study all that we can learn about the way the stars are moving, both by watching them move and by observing them with the spectroscope, we find many interesting and surprising things. Although most of the stars of the sky are moving at random in any direction, yet in some places there are great numbers of them which are drifting along together in a great stream. The five inner stars of the Great Dipper, although so wonderfully far away from each other, are all moving together in this way. Our own sun is one of a group of about one hundred stars which are probably all moving through space together. In some other places the star figures are spreading out: all the stars are moving away from one little area or center. From this we know that a long time ago all these stars were packed closely together, but what it is that is driving them apart we cannot tell.

There is a little star not far from the group called the Great Bear, which is too faint to be seen with the eye, but which is nevertheless one of the most celebrated stars in the heavens. This is because it is moving so wonderfully fast. Although almost twenty-two light years away from us, we see it drifting so rapidly over the sky that in only two hundred and sixty-seven years it would move as far as the distance across the moon. This is an enormous motion for any star. As far as we know there is nothing which can ever stop this Runaway Star. In the course of a very few millions of years it will pass entirely through the great cloud of stars which surrounds us and enter the unknown void that lies beyond.

If all the stars which are so near us that we can see them move could be taken out of the sky, nearly all the brighter ones would be gone. We would still see multitudes of the fainter stars pretty evenly scattered all over the heavens and the stars of the beautiful Milky Way would remain shining in the sky just as before. From this we are sure that the wilderness of suns which make up the Milky Way are inconceivably far away from us.

HOW HOT THE STARS ARE.

When we first look at the stars we may think that they are all white or yellowish in color, but by watching them carefully we soon see that many of them are bluish, and others reddish or orange colored, while still others, which may only be seen in the telescope, are a deep, blood red. These colors are not so clear as those of deeply colored lights, yet we may easily detect them. In the same way we may see that an electric arc light is blue, while the flame of an oil lamp is yellow and that of a Welsbach burner is white. The colors of the stars are sometimes much clearer than these, however, although the most deeply colored stars can only be seen in a telescope. The sun itself is a yellow star.

If we heat a bar of iron, we know that it first becomes red, and then yellow and then white; it does not become white until it is heated very hot indeed. In the same way from the color of a star we can sometimes tell how hot it is, but the whitest or bluest stars are not always the hottest ones. It is believed that every star was once a great, shining cloud of very light matter which we call a Nebula. We think that this cloud slowly shrank together and grew smaller for a very long time, and we know that all the time it was getting smaller it was growing hotter. At last, after it had been shining for ages as a great bright star, it would begin to cool, until it grew so cold that it would be a dark star and not shine at all. The nebulas are generally greenish or greenish-yellow. It is thought that just as the star is beginning to be made it will be blue, and that next it will become white, and then yellow, and at last red. And we think that when it is changing from a yellow to a red color it is hotter than at any other time. We see that some of the stars must be called young stars, although they are really many million years old, while others must be called old stars. And there are almost certainly a very great many which we cannot see because they have cooled so much that, like the earth, they have become dark bodies.

Some of the stars are hundreds or even thousands of times hotter than our sun; if the sun should suddenly begin to pour out as much heat as they do our earth and everything on it would be instantly melted. Yet they are so wonderfully far away that we do not feel their heat at all. It has only been during a few years past that men have been able to make instruments so fine that they can measure with them how much heat we get from the nearest and brightest stars. They find that the hottest does not warm us any more than a single candle would do if it were placed six miles away, and that from the next hottest we only receive as much heat as we would from a candle almost nine miles distant. With the wonderfully accurate instruments with which these results were found it is possible to measure heat to one-millionth of a degree.

The temperature on our own sun is not far from twelve thousand degrees above zero, and very many of these much greater, far distant suns are ever so much hotter than this. Every known metal and rock and substance of every kind that we have ever seen would be instantly melted and turned into a glowing gas if it was brought near such a heat as theirs.

THE BRIGHTNESS OF THE STARS.

In order to tell how bright the stars are, astronomers divide them into "Magnitudes." They say that the very bright stars are of about the "first magnitude" and that the faintest stars which we can see with our eye on a very dark night are of the "sixth magnitude." The faintest star which can be seen with the largest telescope in the world is called of the "seventeenth magnitude," but we can photograph much fainter stars than this.

We receive about two and one-half times as much light from a star of the first magnitude as from one of the second; a star of the second magnitude sends us two and one-half times as much light as one of the third, and so on. There are only twenty-one stars so bright as the first magnitude, but there are about six hundred and thirty thousand of the ninth magnitude, and the still fainter stars are numbered by hundreds of millions.

One star may be brighter than another because it is nearer to us, or because its surface is more intensely bright, or because it is larger. But we are sure that the bright stars are most of them much nearer than the faint ones. One certain bright star may not be so near us as a particular faint one, for a few of the faint stars are quite near, but almost all of the faint stars are wonderfully far away. It is a surprising fact that the second brightest star of the whole heavens is so far away that its distance can not be measured. So that we know that this star is certainly inconceivably much brighter than our sun, probably thousands of times as bright.

If our sun were moved to the average distance of all the stars it would be so faint that we could not see it without a telescope; it is much dimmer than most of the stars in the sky.

STARS WHOSE BRIGHTNESS CHANGES.

Do the stars ever grow brighter or fainter? It does not seem possible that they can keep burning forever without some change, and we might naturally think that they would keep growing dimmer. Yet we have seen that for a long time after their formation they really keep growing hotter and brighter and that then they grow fainter, until at last they are cold and dark. But these changes take so very long a time, probably many millions of years, that we can never hope to see them. We know that we have not seen any change in either the heat or light of our sun, although these are doubtless both changing very slowly.

So we would not expect that we would ever see the brightness of any of the stars change at all; and yet very many of them do change in brightness and some of them in a very sudden and striking way. For instance, there is a wonderful star named Algol, which the ancients called the Demon Star because every little while most of its light seems to go out. It is usually of the second magnitude, but once every two days and twenty-one hours it fades away until it becomes almost of the fourth magnitude; that is, it loses five-sixths of its light. It stays so faint for about twenty minutes and then grows bright again.

The reason why this star seems to suddenly lose its light in this way is because there is a great dark body which moves around it and by coming between us and Algol nearly hides it from our view. With the spectroscope we can see that before the darkening occurs the bright star is moving away from us and that afterward it is moving toward us. By measuring just how fast it moves we can find that Algol is one million miles through and that the dark body is a very little smaller; the dark body is almost exactly as large as our sun. Both of the two bodies, in spite of their large size, are very much lighter than our sun, for we find that both of them together only weigh about two-thirds as much as it does. They are only about as heavy as if they were made of cork. This is one of the many wonderful things which have been found out with the spectroscope. We find that there is a body which we have never seen, and we even learn how large it is, and many other things about it.

Another variable star somewhat like Algol is the second brightest star in the group called the Harp. In this case the second body is bright instead of dark: this causes the star to brighten twice and darken twice each time its companion moves around it. The times of least brightness are when the larger star is in front of the smaller one and when the smaller one is in front of the larger one, but in the second case it will not look so faint as in the first. When neither star hides the other then we receive the most light of all from them. At all times the two stars look just like one to us because they are so close together.

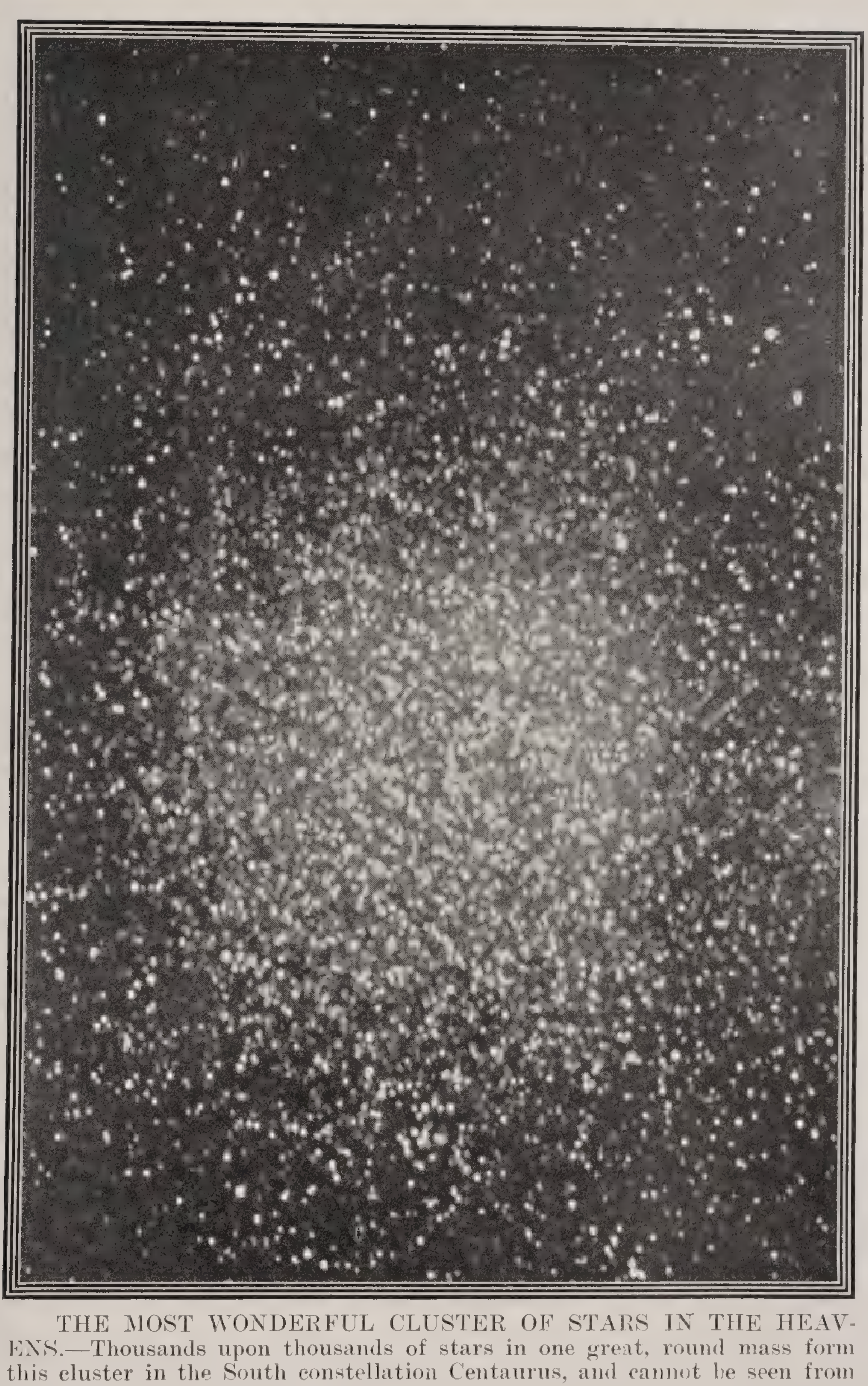
Probably more wonderful than either of these two is a star called Mira, or the Wonderful. This suddenly grows bright about once every eleven months; it then shines out brightly in the sky for about three weeks and may very easily be seen without a telescope. But usually it is so very faint that we cannot possibly see it with the eye. There are many stars which vary in this way, but what is happening to these great suns to make them suddenly flash out with such wonderful brightness we do not know. Some astronomers think that they may be covered with spots as our sun sometimes is and that these spots cause the variations. Our sun is a variable star, for once every eleven years many dark spots appear on its surface, but the change in its brightness from these is so small that we do not notice it. These stars are thought to have many more and much larger spots than the sun. It is strange that most of this kind of stars are red in color, and the redder they are the longer the time is between any two of their brightenings.

There is another most interesting kind of stars which are called New Stars, although these may be only a kind of variable stars which from being so faint that we can not possibly see them flash up only once. They are sometimes wonderfully bright for a few days, but they always fade quickly away again. About fifteen such stars have been seen; a very bright one appeared in 1901.

We do not at all know what causes these striking appearances. We must think that the great body was there all the time, but it was dark and cold so that we could not see it. Perhaps its cold crust was torn apart because it ran into or very near another star, and then the very hot material which was underneath rushed out. Perhaps an entirely cold and solid sun ran into a great meteoric cloud and the collision and friction made it very hot. Whatever causes them they do not last long, but in a few months at most sink down into a faint, greenish, nebulous light, which can only be seen in a telescope.

SUNS WHICH MOVE AROUND EACH OTHER.

There are very many stars in the sky which to our eye or in a small telescope look like single, bright points of light, but which if they are viewed with a



THE MOST WONDERFUL CLUSTER OF STARS IN THE HEAVENS.—Thousands upon thousands of stars in one great, round mass form this cluster in the South constellation Centaurus, and cannot be seen from places on the earth farther than thirty-four degrees north of the Equator.

large telescope are seen to be made up of two stars very close together. What seems to be a single star is really a pair of great suns that move around and around one another, just as the moon moves around the earth. Although the two suns seem to be so near together they are really so very far apart that it requires many years for one of them to pass entirely along its great path around the other. In the most rapidly moving pair so far found one sun moves around the other in a little more than three years, but the time with many of them is hundreds or even thousands of years.

Nearly twenty thousand of the stars in the sky are seen to be double stars when they are looked at with a large telescope. And beside these, there are many bright stars which we know are really double stars although we can never see that they are so by merely looking at them. With these the spectroscope may show us that part of their light comes from a body which is moving toward us and the rest of it from a body which is moving away from us, and then we know that two bright suns are really there, even although they look to us as one. And sometimes when we study the light of a star with the spectroscope we find that there is only one bright star there, but that it is sometimes moving toward us and sometimes away from us. Then we know that it is moving around a great, dark sun. The star Algol was found to be double in this way, but there are very few of this kind of double stars in which the dark body happens to move just between us and the bright body and cut off its light, as the companion of Algol does.

It was a remarkable and striking discovery when astronomers first found that there are many dark suns in the sky which we can never see. They had long known that the whole heavens are filled with a multitude of hot, bright suns, but now they found that there are dark stars there too. How many of these dark stars are there? If it is true, as we are nearly sure it is, that every bright sun is each year drawing nearer to the time when it will have lost all its heat and become cold, may we not think that all the stars which filled the sky ages ago are now dead, and that there are very many more dark stars than there are bright ones? About this we do not know. We believe that new bright stars are now being formed out of the faintly shining clouds called Nebulas, and we are sure that no bright star can last forever. But all goes on so slowly that the whole life of man on the earth is much too short for him to actually see the birth or death of any star.

WHERE STARS ARE BORN.

In thousands of places out among the stars which surround us, we see most beautiful, faintly shining clouds called Nebulas. They are of the most interesting and varied shapes. In many of them the bright material seems coiled around a centre, closer and closer, like the streams of a whirlpool, and these are called Spiral Nebulas. Some are in the shape of a ring, and very many look just like a faint, cloudy star, or like a star which has a bright little cloud around it. But perhaps the most interesting of all are the very large, irregular nebulas. These are of wonderful and inconceivable size; there is a beautiful nebula in the bright winter group of stars named Orion, which is larger than one million globes each twice as far through as the distance from the earth to the sun. And in this wonderful cloud there are several bright stars which seem to be just being made out of the nebulous matter. For this great cloud is much too large to shrink into one single sun; we think that in the long ages to come it will change into a group of many bright stars or into a compact star cluster.

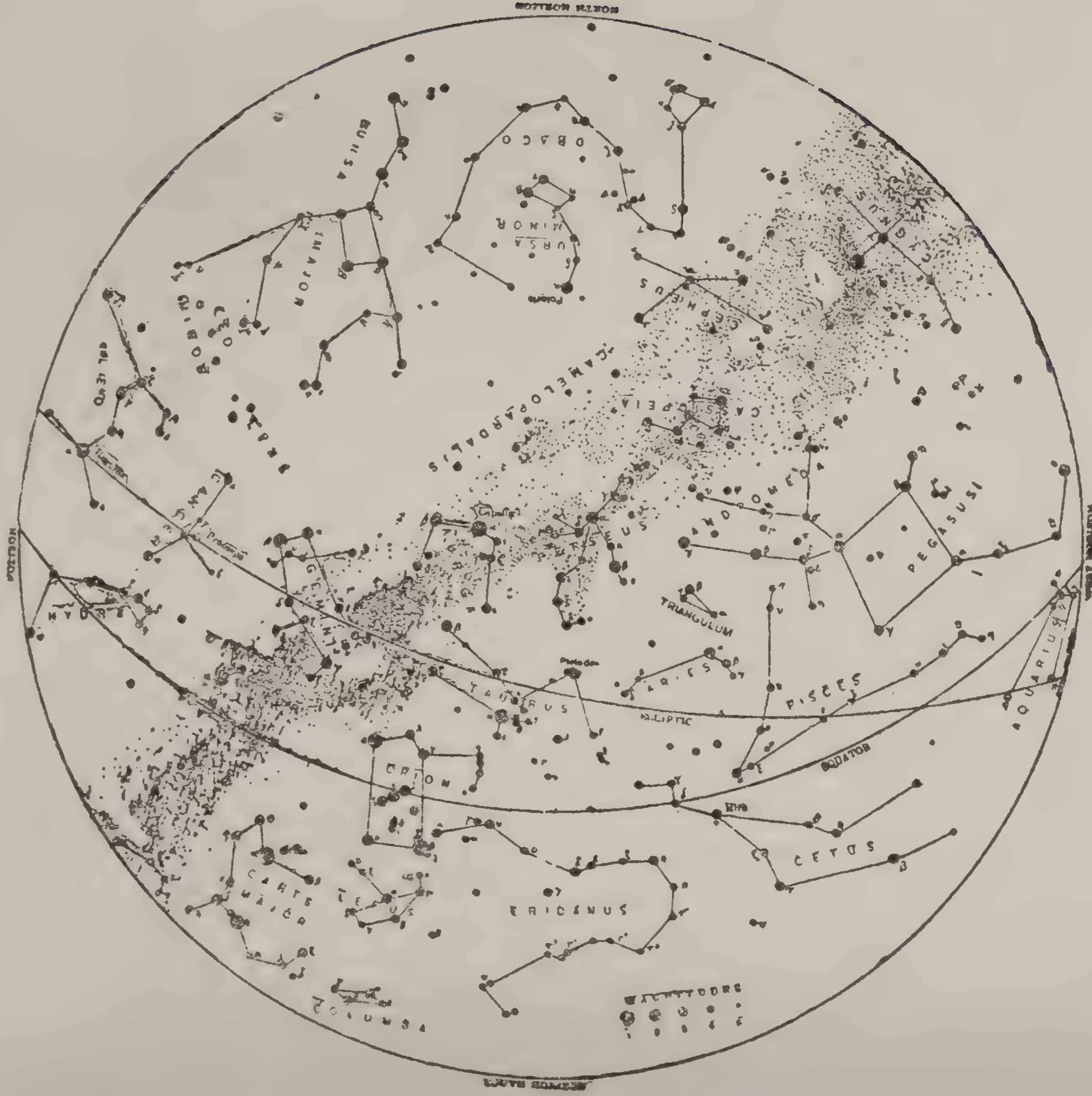
In another part of the sky there is a faint, irregular nebula so long that it stretches well across a whole star group. When we think how immeasurably far away the stars are, so far away that they rush along in their courses for centuries before we can see that they have moved, we can get some idea of how inconceivably large this nebula is. If the path of a swiftly moving star lay right through the nebula and we could watch it speeding along for thousands upon thousands of years, we would hardly see in all that time that it had more than just moved inside the edge of the beautiful cloud. Some astronomers think that this wonderful object is a young nebula; they even think that possibly its bright matter is even now being formed out of something we know nothing about; possibly out of that strange material called ether in which all suns and worlds are moving.

In many parts of the sky where we see very many stars packed closely together they are all surrounded and mixed up with nebulous matter. Sometimes we see black lanes which seem to reach right through the cloud, as if a great star had moved along and swept that part of the nebula out of its way. It is a strange thing that there are few nebulas near the Milky Way, but that there are very many of them in those parts of the sky which are as far off from the Milky Way as possible.

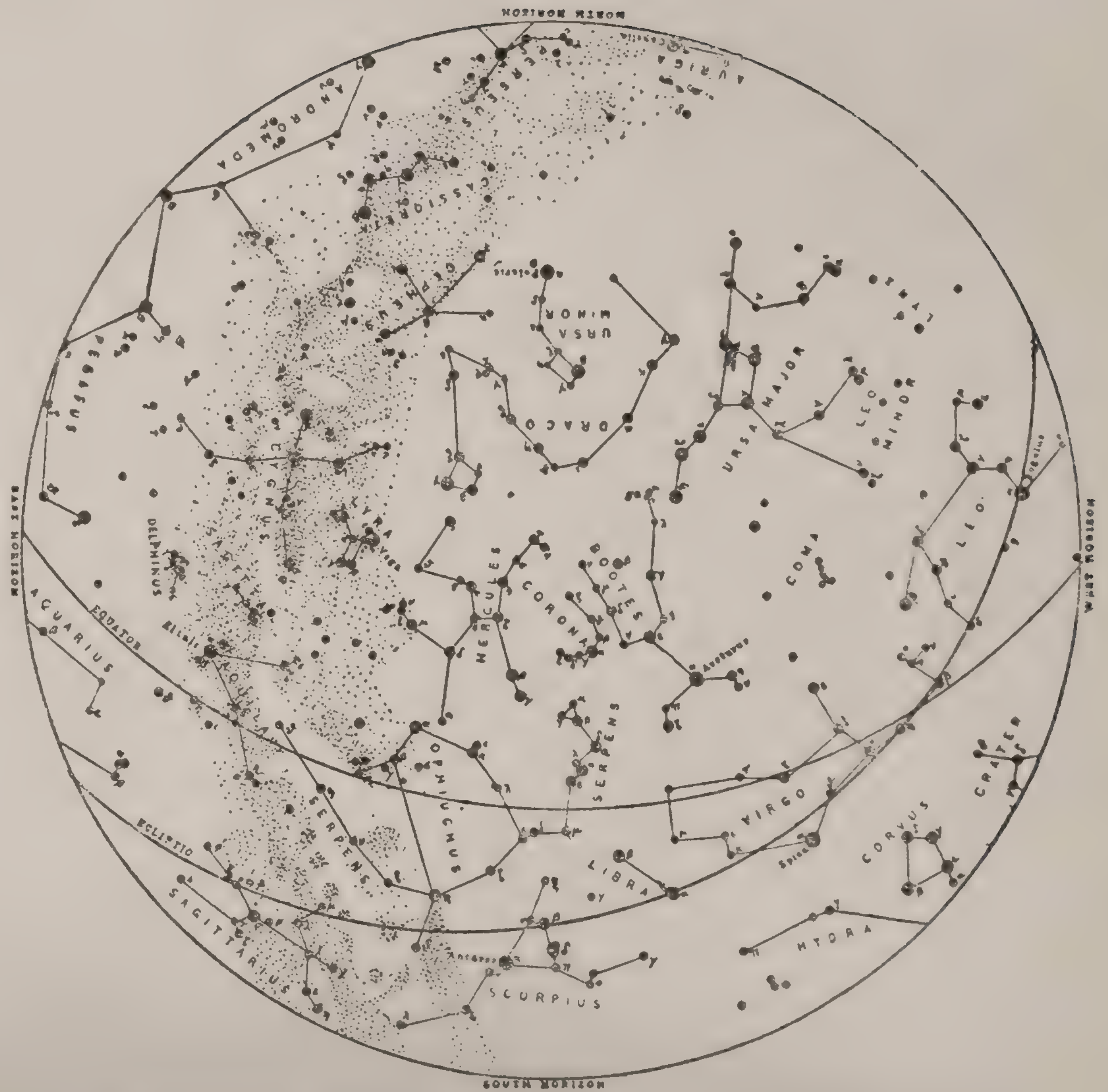
About half of all the nebulas are of a greenish color, and when these are studied with the spectroscope we find that there are two kinds of gases in them, which are called Hydrogen and Helium, and also a new substance which so far we have never found on the earth and which has been named Nebulium. But whether these wonderful clouds are swarms of solid particles mixed up with gases, or whether they are largely filled with little liquid particles, or whether they are so very light that there is nothing solid or liquid about them we do not know.

THE WINTER AND THE SUMMER SKY.

Now that we have learned a little about the wonderful things in the heavens, let us go out of



The bright stars of the Sky as we see them on an early evening of January.



The bright stars of the Sky as we see them on an early evening of July.

doors on some clear, dark evening and look at them. There is so much to see that we hardly know where to begin. If you have a small telescope, or even a pair of opera glasses, one who knows the sky can show you where to find hundreds of interesting things to look at, or if you have one of the books written just to tell you where these things are, you can spend a whole year of pleasant evenings exploring the face of the heavens. In this book we can tell you about only a very few of the things which are most bright and easy to find.

On any evening in January you will see the whole sky filled with the bright winter stars. If you turn toward the south, you at once notice three bright, bluish stars in a straight line; above these there is a very bright reddish star, and below them a very bright bluish one. All these stars and the others near them make up the group called Orion, or the Warrior, and this is the brightest group of all.

The reddish star above is named Betelgeuse and the blue one below is called Rigel. The first is a wonderful variable star; about fifty years ago it suddenly blazed out so brightly that it became next to the brightest star of the whole sky. In a moderately large telescope we may see that Rigel is a beautiful double star, and with a very large instrument its little companion is seen to be double too, so that there is here a wonderful double sun moving around a bright star. Betelgeuse is much older than Rigel and will become dark first; both stars are drawing away from our sun faster than ten miles in each second.

In the southeast you see the very blue star named Sirius, or the Greater Dog Star, and this is the most magnificent star in the whole heavens. Above it there shines out another bright star named Procyon, or the Lesser Dog Star, and this is also of a blue color. Both of the Dog Stars have faint suns revolving around them and men discovered, by mathematics, that the faint stars were there long before they were ever seen with a telescope.

The very red star which you see exactly in the south is named Aldebaran, or the Follower, because it follows over the sky the beautiful little dipper-shaped group which you see just above it. This little cluster is named the Pleiades and it is the most celebrated little group in the heavens. Many nations used to begin their year by the rising and setting of the Pleiades. All of the stars here make up the group called the Bull; the Pleiades are in his shoulder and Aldebaran is exactly at his eye. The star Aldebaran is twenty-eight light years away from us; the light with which you see it started on its journey to you twenty-eight years ago.

The bright yellow star which shines out from the Milky Way exactly overhead is named Capella, or the Little Goat. It is interesting to us because it is in almost the same condition as our own sun, but it is two hundred and fifty times brighter than our sun is.

For our next view of the heavens let us think that we are watching the stars on some warm evening of July. The winter groups have now all gone and the faint summer stars have taken their places, but although they are less brilliant to look at we would find that the delicate summer groups are no less interesting than the more striking ones that we see in winter.

We easily find the Great Dipper in the north, and we have learned how a line drawn through its two front stars points straight to Polaris. In just the same way if we think of a line drawn through the last two stars of the handle this will almost meet a bright, golden-yellow star named Arcturus. This is a wonderfully great sun, at least one thousand times brighter than our own, and it is one of the most rapidly moving stars of all. High up in the east we see an even brighter star than this: this is the beautiful, blue Vega, a star so bright and so blue that it is often called the Arc Light of the Northern Heavens.

Above Vega there is the beautiful Northern Cross, and below it there is the Eagle. But perhaps the most interesting group of all is the bright Scorpion, which we see exactly in the south. This is one of the few star figures which really look like the animals for which they are named. With its outstretched claws, its bright body, and its long tail, which first bends downward and then upward into the Milky Way, it suggests a scorpion to us very clearly. Here there is the brilliant, fiery-red star named Antares, which has a blue sun revolving around it. All this part of the group is filled with a wonderful, nebulous cloud.

In China, Antares was called the Great Fire; in Egypt it was the Crowned Snake; the Persians called it the Royal Star, and the Arabs, the Heart of the Scorpion. The two little groups of stars which are just across the Milky Way from Antares were called by the Arabs the Going and Returning Ostriches, who here pass back and forth from the beautiful celestial river.

ARE THERE OTHER UNIVERSES BESIDE OUR OWN?

We have learned that all around us there is a wonderful cloud made up of millions upon millions of great suns which are so far away that they look to us only like little, bright points of light. And beside these there are great, dark suns in the cloud which we can not see at all, and wonderfully large nebulas out of which new stars will sometime be made. Does this wonderful cloud go on forever, or if we journeyed far enough would we come to its edge and look out into a great empty space where no stars are?

We think that our own cloud, the cloud of which our own sun is one little yellowish star, is of a roundish, flattened shape, and that when we look at the Milky Way we are looking through the greatest thickness of it. Perhaps it is a great spiral, somewhat of the same shape as the whirlpool nebulas which we see in the sky, but how infinitely much larger! It is believed that a ray of light could not pass through it from one edge to the other in less than three or four thousand years.

Far out in endless space there may be other whole universes of stars like this one. About this we do not know, but if there are really other star clouds like our own they are so far away that we have not been able to find them even with the largest telescopes.

CHAPTER III.

Our Sun and Its Family of Worlds.

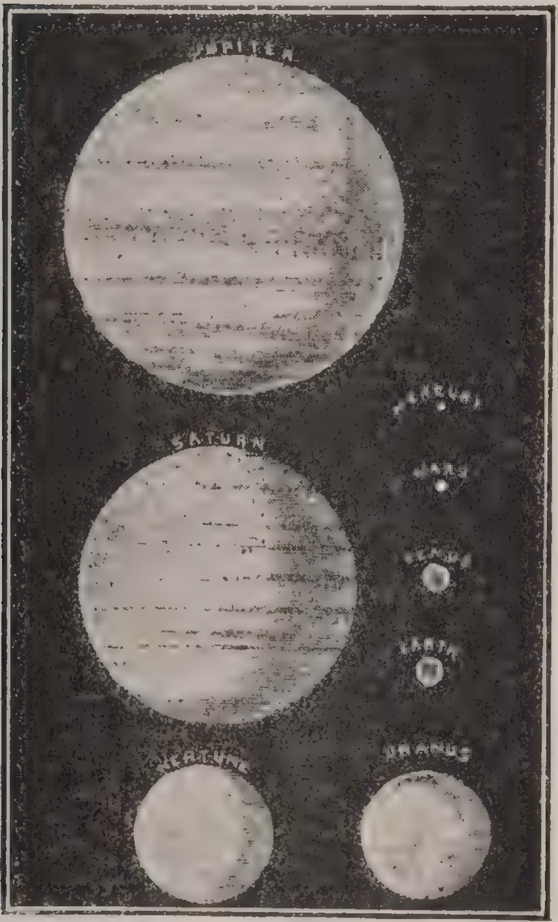
THE EIGHT WORLDS WHICH BELONG TO OUR SUN.

OUR sun is only a little star and yet it is of much more importance to us than all of the other stars together. All day long it floods our world with light; it climbs high in the sky in the summer, and then our weather grows warm; and when in winter time it sinks a little lower, our cold season comes again. If it were not for the sun there would not only be an intense, unending darkness over the whole world, but it would also be so cold that nothing at all could possibly live here.

This is all because we are so very much nearer to the sun than to any other star. Indeed, our little world belongs to the sun, just as the moon belongs to the earth. The pull of that great body keeps us always moving around and around it in an almost round path. If this pull could ever stop, our world would journey off into the cold of space: as we drew away from the sun we would rapidly get colder and colder until soon all the life on the earth would be destroyed. But this can never happen. The sun will always keep pulling our world and we will always stay at almost exactly the same distance away from it as we are now; that is, just so far away that its heat will make our earth a warm and pleasant world so long as the sun itself is hot.

Our earth is a round, dark world which is ever so much smaller than the sun is. And when we think of how far from one another the stars are, we seem to be almost right against the sun. We are so near it that if a telescope a hundred times larger than the largest telescope ever made could be carried to the nearest star, no one could possibly see our earth with it; the earth and the sun would seem to be so near together when viewed from that star that they would look like one single point of light. And so it is right to say that our earth belongs to the sun, which controls its motion and always keeps it so near itself.

But ours is not the only little world which is very near the sun. There are seven others, all moving around the sun in almost round paths, and all so near it that they could not be seen at all from the nearest star. The nearest of these worlds is less than half as far from the sun as we are, and more than seven times as much light and heat is poured down upon it from that hot, central body as is sent to us. The world farthest away is more than thirty times as far from the sun as we are; if our earth were placed where this world is we would receive only one-nine-hundredth part as much light and heat as we do now, and everything would die from cold.



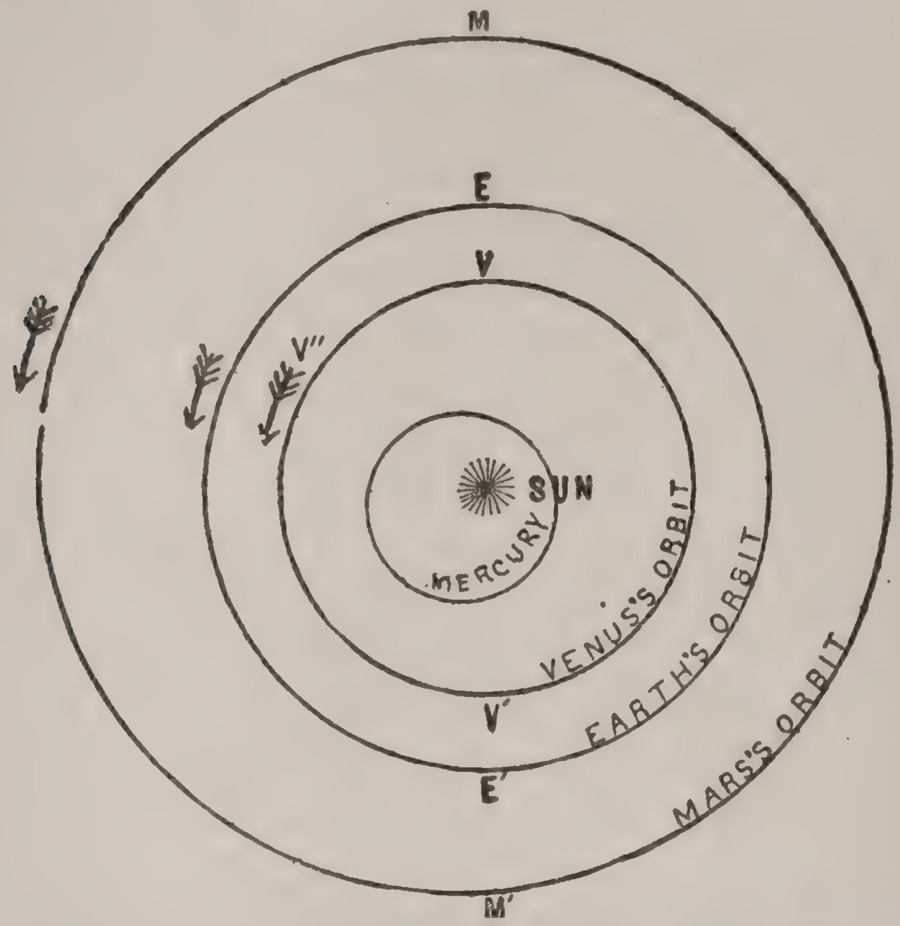
The Eight Worlds which revolve around the Sun. This picture shows how much larger the outer worlds are than our earth.

The four worlds which are nearest the sun are all a little smaller than our earth, and they are all cold, solid bodies just as our world is. The inner one of these is named Mercury, the next is Venus, the next is the Earth, on which we live, and the one which moves in a path just outside of the path of the earth is named Mars. The other four worlds are much farther away from the sun than these, and they are very much larger. The smallest of them is sixty times larger than our earth, and the largest is one thousand three hundred and fifty-five times larger. Yet they are not nearly so interesting to us as the smaller worlds are because they are very unlike our earth; they are all so very hot that they are not even solid worlds, and we know that nothing at all could live on them. The names of these four large, outer worlds, beginning with the one which is nearest the sun, are Jupiter, Saturn, Uranus, and Neptune. All of these eight worlds which move around the sun are called Planets. None of the planets are hot enough to shine by their own light as the stars do; we only see them because they are flooded with light from the sun.

HOW THE PLANETS MOVE AMONG THE STARS.

All of the eight worlds which belong to our sun are very much smaller than the sun is; we would have to take more than one thousand balls as large as the largest of them to make a single ball as large as our sun. And so even the largest of them is wonderfully much smaller than any of the stars which we see in the sky. But they are all so very much nearer to us than the stars are, that some of them sometimes look brighter than even the brightest stars.

When a bright planet is seen shining in the sky it looks so exactly like a star that one who did not often look at the heavens would not know whether it was a star or not. But one who had spent much time studying the beautiful star groups would know at once that it was not a great, far distant sun which he was looking at, but only one of the dark worlds near our own. For he would know that the stars hardly change their places among each other at all, even if watched for centuries; he would have learned all the brighter stars by name and just where to look for them in the sky, and many other interesting things about them. And if among the stars of any group he saw a bright object shining out which was not usually there he would be sure that this object was a planet.



The paths of the four Planets which are nearest the Sun. The other Planets are much farther away: if the path of Neptune was drawn on this picture it would be four and one-half feet across.

The planets shine in the sky just as the stars do, but, very unlike the stars, they are seen to be all the time moving. It is very easy to see why this is so. Think of a bright light, or sun, with eight great circles drawn around it. And think of eight worlds, of which our own earth is one, always moving in these circles around and around the sun. It is very clear that as we stand on our moving earth and watch the other bodies we will see them moving too; sometimes they will be in one direction from us and sometimes in another. And far outside of the circles, at an inconceivably great distance away, is the whole round sky full of stars. As we watch the moving planets we will see them sometimes pass in front of one group of stars and sometimes in front of another. And so they will seem to be constantly changing their places among the stars of the sky.

It is very interesting to watch the motions of these worlds and to see how they change in brightness as they move nearer and farther from our earth. The paths which they seem to follow among the stars are sometimes very complicated; sometimes they are moving eastward and sometimes westward; sometimes they journey into the part of the heavens which is above us in the morning, and sometimes they shine out in the evening sky. Sometimes their motion happens to bring two or three of them to the same part of the heavens at once, and they make a beautiful and striking little figure as they shine out near one another. But we must not forget that though they seem to be close together they are at very different distances away from us, and so they are not really near each other as they seem to be. When a planet is seen in the morning it is often called a Morning Star, and when it is seen in the evening it is called an Evening Star, although, of course, it is not really a star at all. The very early astronomers, who did not know what they are, called them Wandering Stars.

When we look at the planets with a telescope we see very much that is beautiful and interesting. They are all so near us that they look like large, round worlds and not merely like bright points of light as the stars do. On some of them we see markings that may be land or water, and great white patches that may be snow, and some of them have many moons that move around them, just as our moon moves around the earth.

HOW OUR SUN AND ITS FAMILY OF WORLDS IS DRIFTING THROUGH THE GREAT STAR CLOUD.

If all the other stars are moving very fast in all directions, is it not probable that our sun is moving too? But if so, it must be carrying our earth and all of the other planets with it on its journey, for if it did not do so these worlds would soon be left behind as the sun drew away from them. Instead of this we know that they are always kept near the sun, moving around and around it in their almost round paths. If we find that our sun is moving it will be most interesting to learn in what direction it is going and to find out where it will carry us during the centuries that are to come.

From very many measures it is found that we are being carried straight through the great star cloud toward a part of the sky very near the bright star Vega. We know that this is so because we see the stars there widen out, or draw away from each other, as we move nearer them, exactly as the trees in a forest would seem to us to separate from each other if we should walk toward it. At first we might be so far away from the forest that the trunks of the trees would seem to almost touch each other and to form a solid wall, but as we drew nearer and nearer to them the space between them would seem to widen, until, when we got very near indeed, we might see that they were really very far apart. And it is exactly the same way with the stars in the part of the sky toward which we are going. They seem to be separating from one another, but they are still so very far away that they move only a very little. And the stars in the part of the sky away from which we are moving seem to be drawing nearer together for a similar reason.

But there is another way that we can find out how our sun is moving, and by this way we can also find how many miles we go on our journey each day. When we observe the stars near Vega with the spectroscope, we find that on the whole these stars seem to be moving toward us about thirteen miles each second; and the stars on the opposite side of the sky seem to be going away from us just as fast as this. This shows us that we ourselves are really moving straight toward the first stars and away from the others. The path of our moving sun which we find in this way is just the same as the path which we find by the first way.

So there can be no doubt that our sun is ever rushing along through the great star cloud and carrying all its eight worlds along with it. It moves thirteen miles each second, and this is so fast that during each hour of our lives we are carried nearly forty-seven thousand miles farther on our endless journey. We are going almost directly toward Vega, but this star is so far away that we will not pass to the other side of it until five hundred and fifty-eight thousand years from now.

As the centuries go on and we pass farther and farther through the great star cloud which surrounds us, we will gradually become aware that all the stars of the heavens are drifting past us. And by very carefully measuring how fast they seem to move, we will find exactly how far away each one of them is, and so learn the true size and shape of our entire universe. But this knowledge will not come to us either in this century or the next, for in so short a time as this we will not have yet traveled far enough. It is to astronomers who will be living on our world many hundred years from now that this will be known for the first time.

CHAPTER IV.

Telescopes and Observatories.

HOW CROWDS OF PEOPLE CAME TO LOOK THROUGH A WONDERFUL TUBE.

IT was only three hundred years ago that a man looked at the heavens for the first time with a telescope. During all the many centuries before this men had only seen the things in the sky as we may see them if we go out of doors and look upward on any clear, dark night. And so for many centuries they did not know what the heavenly bodies are. Some thought that the stars are great stones thrown upward from the earth and set on fire by their motion; others believed that the particles of sunlight which fill the air during the day were gathered together at certain points during the night, and that these points are what we call stars. And although they slowly grew certain that the stars must be great lights a long way off, they had no idea of the fact that there is really so wonderful a multitude of suns spread out around us. Still less did they know how the bright planets, which looked to them like stars moving around among the other stars, are really great worlds which go around and around the sun just as our world does.

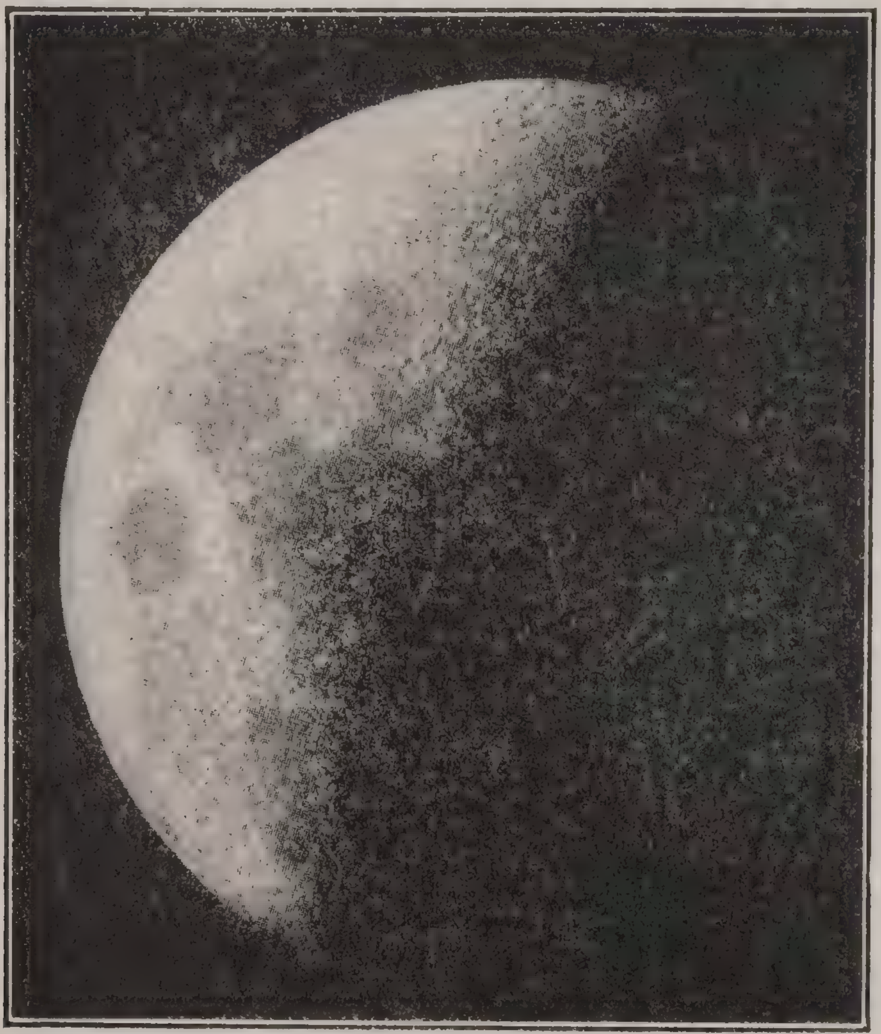
Yet, even though they had no telescopes, the early astronomers found out a great many things. Many thousands of years ago they knew that our world is round, and they had measured how large it is. They could see and measure how the sun and moon and planets seem to be moving around our earth and they could foretell where these bodies would be seen in the sky at any time. They also knew just when the new years and the different seasons would begin and when the light of the sun and moon would be darkened by eclipses. In short, they could find out how the heavenly bodies seem to move, and they could even in later centuries measure the distances away to some of them, but as to what these bodies really are like and what they are made of they had no means of knowing.

But when the first telescope was pointed to the sky what a new world for discovery and study was given to us! The great sun was seen to be slowly turning around, just as the earth does; the moon was found covered with craters and mountains and great plains; the planets were round worlds, some of them with moons of their own and some of them seeming to change their shape, just as our moon does, from a narrow crescent to round and then back to a crescent shape again. And all over the sky there were thousands upon thousands of stars which were too faint to be seen by the eye and had never been looked upon by man before.

The first astronomer who ever looked through a telescope was named Galileo. This great man, who was then staying in Venice, learned that a spectacle maker of Belgium had the year before fixed two spectacle glasses in a tube in such a way that they made all objects seem nearer. Galileo at once understood why this was so, and he set to work with the greatest eagerness to see if he could not make so wonderful a tube himself. He obtained a lead tube which had been an organ pipe and he selected two round pieces of glass of a certain shape and fixed them in its ends. Upon looking through it he was greatly delighted to find how much larger and nearer it made everything look. In a few days he had made a better telescope, and with this he and the rulers of the city climbed to the tops of the houses and to other high places from where they looked at the surrounding country with the greatest surprise and delight. It is not hard for us to imagine what an excitement there was when the people heard of this new thing. Galileo remained in Venice a month, and during all that time crowds of people were with him from morning until night, waiting for a chance to look through his wonderful tube.

WHY A TELESCOPE MAKES THINGS LOOK NEARER.

When we look through a telescope everything seems nearer to us only because it looks much larger and clearer. The large glass at the upper end of the telescope makes a perfect image or picture of whatever the telescope is pointed at, but this image is not very large. The image made by the glass in the large



Photograph of the Moon taken with an eighteen-inch telescope. This shows exactly how large the image made by the large glass in this telescope is.

end is very near the other end of the telescope; if we hold a ground glass or a piece of white paper at this place we will see on the glass or paper a bright, clear, little picture of the object at which the telescope is pointed.

We could next take a common magnifying glass and holding it in our hands, magnify the bright little picture as much as we wished. But it would be awkward to keep holding such a magnifying glass in our hand, so one is fixed to the end of the telescope itself at just the right distance from the picture to magnify it clearly. This little glass is called the eye-piece. So that the eye-piece in the small end of the telescope is nothing but a little magnifying glass. We do not need to first hold up a paper on which the bright little picture comes and then to magnify the picture on the paper, because we can see it in the eye-piece even more clearly if there is no paper there.

When we look at the moon with our eye, only so much moonlight goes into our eye as can get through the little round pupil, and this is only about a quarter of an inch across. But if we point a telescope at the moon nearly all of the moonlight which falls on the large glass is gathered together in the little image which we see, and so this may look dazzlingly bright. If the large glass is three feet across, more than twenty thousand times as much light will pass through it as would enter the pupil of our eye. For this reason a large telescope shows us a multitude of things which are very much too faint for us ever to see without a telescope.

The little picture which the large glass makes looks very clear and sharp to us, but it is really not a perfect picture. If we should magnify it very much with a very strong magnifying glass, or eye-piece, we would see that the edges and markings on it were not perfectly sharp and clear lines, and if we tried to magnify it too much it would all look blurred.

And the more we magnified it the fainter it would look. Now the larger the glass in the upper end of the telescope is the more light it will gather in and the brighter the little picture will be which we are magnifying. And the larger the glass is the more we can magnify the picture without its becoming blurred. It is therefore clear why we can not only see much fainter things but why we can also make things look much larger in a large telescope than in a small one.

There is so much to be seen in the heavens and there are so many things that we are anxious to see more clearly that no expense or labor are thought too great when devoted to making a glass as large and as perfect as possible. There is one in the great telescope of the Yerkes Observatory, near Chicago, which weighs more than half a ton and which cost $125,000. To cast so large a piece of glass and to make it of just the right shape is a wonderfully long and difficult labor. But this telescope will magnify three thousand times; a man twenty miles away would be brought as near as thirty feet and we could easily recognize him. If there were cities and towns on the moon, we could see them with this telescope very clearly.

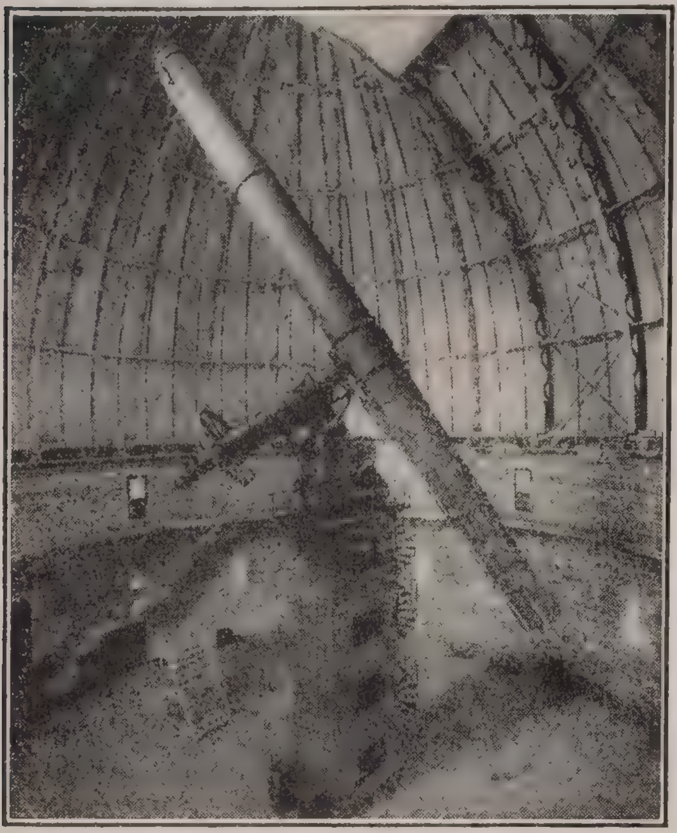
A GREAT TELESCOPE.

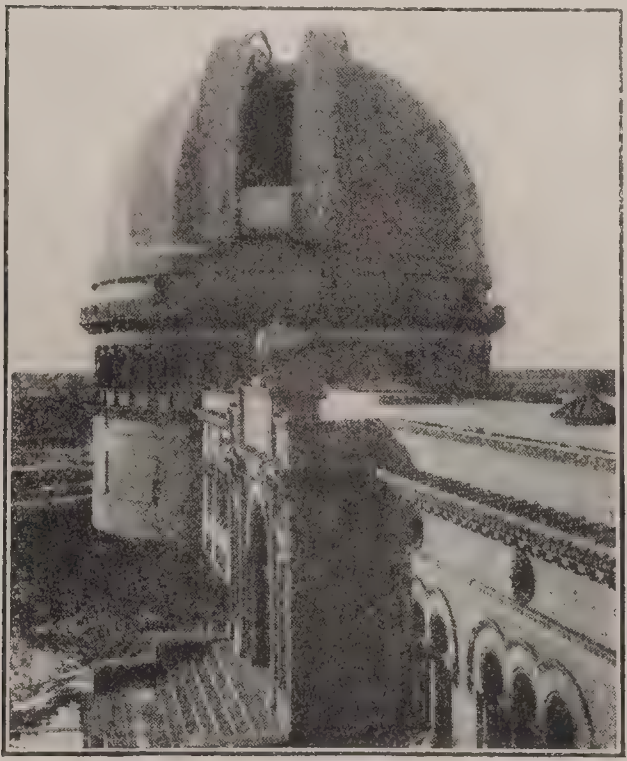
The buildings in which telescopes are mounted are called Observatories. It is here that astronomers work all night long, studying the wonderful things which there are in the sky. If you should visit a large observatory you would see many different buildings, all with telescopes of different kinds in them, but the largest building of all would attract your notice first because of its strange appearance. This would be a large, round building with a great roof on it which is of the shape of a half ball, and it is inside of this roof that the largest telescope of the observatory is mounted.

If we go into this large building we find ourselves in a circular room, and in the exact center of this there is a great steel pier on the upper end of which is the enormous telescope itself. The great round tube towering so high above us is an impressive sight; it may be fifty or sixty feet long, so long that it would reach from the ground to the top of a six-story house, and it may weigh twelve or fifteen tons; and yet it is balanced so beautifully on the top of the great pier that by hardly more than a touch we can move it in any direction. As we point it toward different parts of the sky we see that its upper end is always a few inches inside the roof which covers it, and now we see that this roof is made round so that the telescope will have just room enough to turn in any direction underneath it.

The Lick Observatory on Mount Hamilton, California.

Reaching from the highest point of the roof to the bottom of it there is a wide shutter, and when we open this we see a strip of the sky which extends from the ground to the point of the heavens exactly overhead. The whole roof rests on wheels so that we can turn it entirely around or move it until the open shutter is turned toward any part of the sky which we may wish to see. By turning the telescope and the roof both, we can thus look at any object in the heavens. But the stars and all the other heavenly bodies are continually moving; they rise in the east, move slowly over the sky, and finally set in the west. Therefore, inside of the pier, near the upper part, there is a very accurate clockwork which keeps the telescope moving just as the stars move. If we point the great tube at a star or planet and set the clock-work going it will keep pointing at the star hour after hour as it moves across the sky.


The Great Telescope of the Yerkes Observatory, near Chicago.


The Outside of the Yerkes Observatory. Showing the great telescope pointing out of the dome.

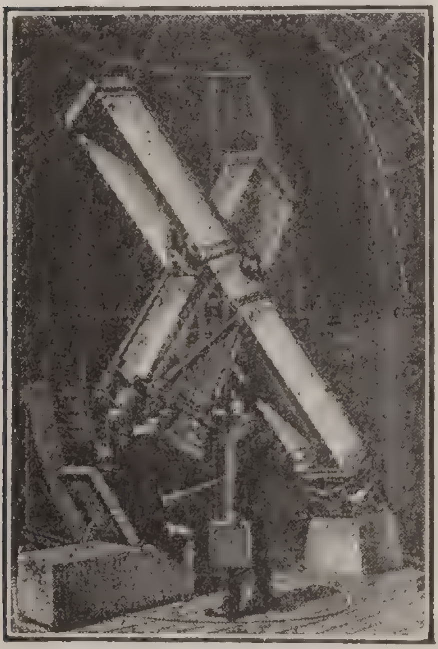
If the telescope is a very large one the roof may weigh more than one hundred tons. It is, therefore, turned around by machinery, and another machine moves the whole floor up or down with everything on it until it is at just the right height for the astronomer to look easily through the tube. The great pier which holds the telescope never touches the floor in any observatory. It always goes down through a hole in the floor and rests on a very large stone pier which is built deep into the ground.

A great telescope is a wonderful thing. The whole huge mass which is balanced so beautifully and which moves so easily is a marvel of skillful work. And although it is not so striking to look at, the most wonderful part of it all is the great glass in its upper end. It is for this that all of the rest is made, and if this by months or even years of patient work has not been brought to exactly the right shape, the whole telescope is a failure. But when this is as perfect as the skill of man can make it, and when the astronomer sits at the eye-piece studying some far-distant world which is kept steadily in his view by the delicate mounting and clockwork, he cannot help but feel thankful that he is living in this age, when for the first time in the history of the world so wonderful an instrument can be built.

HOW ASTRONOMERS MAKE PHOTOGRAPHS OF THE STARS.

Sometimes, instead of looking at the stars or measuring them with a telescope, the astronomer prefers to photograph them with it. He then fastens a very sensitive photographic plate to the big tube so that it is exactly at the place where the image falls which is made by the large glass in the upper end. If the object to be photographed is bright, so much light will be gathered in by the large lens that the picture may be taken in a very short time, but if it is very faint it may be that the large telescope must be kept pointed at it for many hours before a good picture is made.

It is a very wonderful thing that we can photograph objects with any telescope which are so very faint that we could never see them with it. If we look carefully at a very faint object it will not seem to us to grow any brighter, nor will we see it much more clearly even if we look for a long time. In fact, after a little while our eyes will grow tired and we can not see it so clearly as at first. But if we take our eye away from the telescope and put a photographic plate there, just the opposite will happen. As we will tell about later, there are a very great many little waves of light coming from the faint object and passing down through the large glass and hitting against the sensitive plate. Perhaps the object is so very faint that even after the little waves have been striking against the plate for an hour, or even for two or three hours, we see no picture of it. But just as a constant dropping of water will wear away a stone, so if we wait long enough the light waves will begin to change the plate and a picture will begin to appear. In this way thousands of beautiful pictures have been made of wonderful objects in the sky, very many of which are very much too faint ever to have been seen by the eye even in the largest telescope.


Photographing the Stars.

For taking photographs the astronomer uses a kind of double telescope, made of two great telescopes fixed firmly together, side by side, so that both will point to exactly the same part of the sky. The photograph is made with one of these, but the other is to look through and is used as a pointing telescope. To get the best pictures the glass in the large end of the photographic telescope must be made of a little different shape from the other, because a telescope which will show objects most clearly when we look through it will not make the best pictures of them.

All the time that the picture is being taken the astronomer must sit at the end of the pointing telescope and keep it pointed at just the right part of the sky. Hour after hour he patiently guides it, sometimes even from night-fall until day begins to break. And sometimes more time than this is spent on a single picture, the astronomer carefully covering it before daylight and pointing it to exactly the same part of the sky on the next clear night. Whenever we look at a beautiful photograph, covered with thousands of stars and nebulas, we may be sure that to make it for us some astronomer must have worked for a long time with the greatest patience and skill.

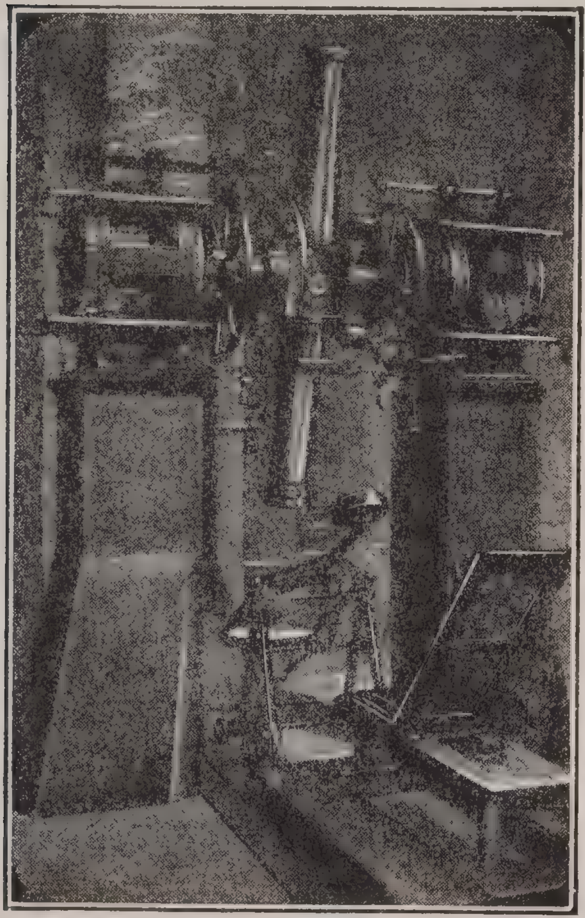
WHERE ASTRONOMERS WORK.

Now that we have visited the largest building, let us go next into some of the smaller houses and see what these are for. We find that they contain many beautiful instruments of different kinds, some built for one kind of work and some for another, but each of them just as important in its way as the big telescope itself. Many astronomers spend their whole lives working with these smaller instruments, and very much of what we have learned about the worlds around us has been found out with them.

We notice at once that the telescopes in these smaller buildings are not very large. Most of them are built on very solid stone piers and we cannot point them to different parts of the sky as we could the large telescope. Many of the little telescopes can only be pointed in a north or south direction; another is so built that it can only be pointed east or west, while still another is always directed straight upward to the point of the sky directly overhead. These telescopes have very fine circles of silver attached to them marked with little lines so fine that they must be looked at with microscopes. They have wonderfully accurate levels to show when one of the supports gets the least bit too high or too low, and many beautifully made attachments of steel and other metals.

It is clear that these telescopes are not built just to look at things with. In fact, the telescopes are the least important parts of the delicate machines: it is the wonderfully accurate circles and the beautifully made machinery around the telescopes which is important here. And it is all made so carefully so that we can tell with the highest possible exactness in just what direction the little telescope is pointing.

The most important of all these instruments is called the Meridian Circle; it is with this that we find the exact positions of the stars on the sky and make accurate maps of them. The telescope can here only be moved in a north and south direction; when it is pointed upward at any height the astronomer sees all the stars of one little strip of the sky passing steadily along in it as they move slowly from east to west. He finds from his clock when each little star reaches the middle of his telescope, and he finds how high up in the sky it is by reading the very fine circle with the four microscopes. In this way the positions of many hundred thousands of stars in the sky have been found. The instrument is so wonderfully accurate that if one of the little marks on the level is only one-millionth of an inch too high the astronomer can see it. If a little point on the earth five miles away should move only one-quarter of an inch he could measure how it was moving. It is with the meridian circle that it was found how all of the stars are rushing along in different directions through space and that our sun is itself moving through the great star cloud. And from very accurate measures with this instrument the astronomer finds how



A Meridian Circle.

the moon and planets move and how far away the stars are and many other wonderful things.

In one of the little buildings, or perhaps in a room deep down underground, there is a very fine clock. And there is also a telescope that looks much like a meridian circle with which the astronomer, by observing the stars, can find out how much too fast or too slow the clock is. His measures are so exact that even if it is only a few hundredths of a second wrong he can tell just how much wrong it is. With the telescopes which are pointed east and west, and with those which point straight upward, he finds exactly where his observatory is on the earth, and how the motion of the earth is disturbed by the pull of the various heavenly bodies.

Although the instruments in the little buildings are not very large, and although at first sight they may not seem so interesting as the great telescopes are, they are really no less wonderful. And much of the very most important work in astronomy is being done with them.

CHAPTER V.

The Sun, the Ruler of the Solar System.

WHAT KEEPS OUR EARTH WARM.

IF you have read the first pages of this book, you have learned how our sun is a hot star, one of the very many stars which we may see shining in the heavens every night. And you have learned that there are eight little worlds moving around our sun, and that it is on one of these little worlds that we live.

Though very many of the stars are much larger and hotter suns than ours, our own sun is much more important to us than any other star can be. It is like a great, wonderfully hot furnace, pouring out heat and light in every direction, and our world is moving around and around it, never getting much farther away or much nearer to it at one time than at another. If our world could ever move much farther away from this great hot sun, all the lakes and oceans would become frozen and we would all die from cold: if we could ever be drawn much nearer to it everything would be burnt up by its great heat.

Every morning we see our beautiful sun rise above the ground in the east and climb higher and higher up in the sky until noon; then it begins to move downward again, until at last it sinks below the ground in the west. All day long it is pouring its light and heat down upon us, and if it were not for this great, hot body always keeping our little world warm, every living thing on the earth would die. The sun is like a great furnace, a long way off, which is always burning to warm us.

If we think about it, we will see that all the pleasant warmth which we enjoy on the earth comes from the sun. It is the heat of the sun which warms the earth in summer and makes everything grow. In winter we burn coal or wood in our houses, but if the sun had not been shining on the earth no trees would have grown and we would have no wood to burn. And, as we will tell about by and by, even all the coal which is found deep down in the ground was once great trees which grew because the sun shone on them. The sunshine which filled our earth long ages ago made these trees grow, and after a long time they changed into coal. So that if our sun had not shone on the earth so very many years ago we would not have any coal to burn.

In summer time the sun sometimes rises as early as four o'clock in the morning and mounts so high up in the sky that it does not set until eight o'clock in the evening. On a hot summer's day we can often feel the heat of the sun beating down on us, in just the same way that we feel the heat of a hot stove if we get too near it. But in winter the days are much shorter and the sun is not nearly so high up in the sky, and that is why it is so much colder in winter than in summer. For all the warmth of the whole earth comes from the sun.

If the sun was not very large and very hot indeed it would have to be very near our world to keep us so warm. But it is really so very far away that it is hard to explain how far it is. Sometimes people make a journey all the way around our world; it is almost always at least a year before they get home again. We think that such a trip is a very long one, but a journey to the sun would be nearly four thousand times as long. If they went no faster on their trip to the sun than when they travelled around the earth, they would die of old age before they had gone more than one-fortieth of the way, even if they started on the day when they were born and lived to be one hundred years old.

Suppose that the fastest railroad train could start straight toward the sun. Day after day, and year after year, it would fly along without ever stopping, but not until it had been running for two hundred and fifty years would it reach the end of its journey. If when the train started the engineer was a little boy ten years old, he would have had time to grow into an old, gray-haired man of ninety before the trip was one-third finished. The swiftest cannon-ball, if it could be shot from the earth to the sun, would not hit the sun until nine years after the cannon was fired off. The sun is ninety-two million nine hundred thousand miles away.

HOW LARGE OUR SUN IS.

We see that the distance to the sun is so very great that we cannot understand it. Even all the miles from one side of our world to the other are very small indeed compared with the very many more miles which lie between the earth and the sun. We will now try to see how very large our sun must be to keep us warm when it is so very far away.

There are some very large and very hot furnaces which men build to melt iron. The heat from these is so great that you could not go very near them without getting burnt. When a house burns up, the great heat sometimes burns the paint or even melts the glass in the windows of houses which are across the street. But if you go only a short distance away from the furnace or from the burning house, you will hardly feel their heat at all. A little walk of five minutes, or even less, will take you so far away from them that you cannot feel them warm you.

If going so very short a distance makes so much difference in the warmth we feel from a hot body, how wonderfully large and hot our sun must be to warm us when it is so many millions of miles away. Indeed, if our whole earth could be heated until it was white hot and then placed as far away from us as the sun is, we could not feel any of its heat at all.

When we wish to show what a thing is like we often make a little model or image of it. If this was a little model of an engine, the smoke-stack and the cab and the wheels, and all the other parts would be of the right sizes, but they would all be very much smaller than they are in a real engine. In just the same way we can make a little model of the sun and earth. The sun is a great ball which is round like the earth, so let us take a large ball, two feet high, to be the sun. This ball will reach nearly from the floor to the top of a table. Then for the earth we must have another ball, and if our model is to be right, the earth-ball must be a very little one indeed. The second little ball must be less than one-quarter of an inch through; that is, it must be only as large as a very small pea.

The big ball and the little pea will be of just the right sizes to stand for the sun and our earth. Suppose we have made the big ball hollow, with a small hole in the top, and that we wish to fill it up with the little peas. We will need to have nearly three and one-half bushel baskets full of them. And if we drop one hundred peas into the big ball every minute, it will be nine days before we get it full. For the big ball will hold one million three hundred thousand of the little peas.

This shows us how very much larger our sun is than our earth. We had to put one million three hundred thousand peas into the large ball before it was full, and in just the same way, one million three hundred thousand great balls, each as large as our whole world, would have to be taken to fill a very large globe as large as our sun. If we make a picture which shows both the earth and the sun at once, the earth looks only like a little round black dot on the large picture of the sun.

We see that the sun is so wonderfully large that when we think of it even the whole of our world seems very small. And when we know that every part of the surface of this great sun is very much hotter than the very hottest part of any furnace that has ever been built, we can understand how it is able to keep always pouring out enough heat to warm our world, even though it is so very far away from us.

WHAT WE SEE ON THE SUN WITH A TELESCOPE.

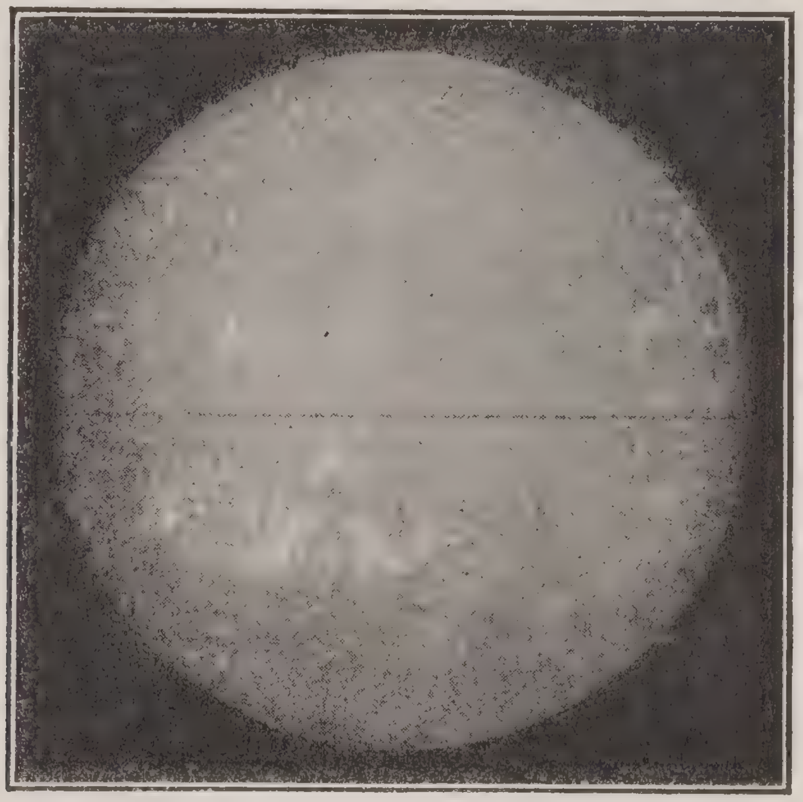
The sun is so bright that we should never look straight at it, except sometimes when it is very near setting or rising. But if we put on a pair of very dark spectacles or look at it through a piece of colored glass, we can see it clearly without hurting our eyes. We will then find that it is a round, very bright ball, and sometimes, though not very often, we can see that it has a few little black spots on it.

If you have a small telescope or a pair of opera glasses, you must be careful never to look at the sun with them, because if you did so you would certainly hurt your eyes very much and might even make yourself blind. But a little attachment, or even a very dark shade, can be bought to put in the telescope, and then you can look at it without any danger.

When a picture is made of the sun it is a perfectly round, very bright ball, and it is often seen to have groups of black spots on it. These spots look very small in the picture, but this is only because the sun is so very far away from us. Even the smallest spot is larger than our whole earth.

If you kept looking at the sun you would see that the whole ball is slowly turning around. As it turned the spots would draw nearer and nearer to the right hand edge, and they would at last be carried around to the back of the sun so that you could not see them. Meanwhile, perhaps, you would see more spots come around the left hand edge, and if you looked long enough, the sun would turn entirely around so that you could see every part of it. But it turns very slowly. It takes it twenty-seven and one-third days to turn around once. After a spot was seen to come into view around the left hand edge it would be seen moving across the sun for about two weeks before it at last passed around the right hand edge and was lost to view.

In a large telescope we can see much more that is interesting than in a small one. In the first place, all the bright ball which seemed so white and smooth in a little telescope is seen to be a tangled mass of very many little white and dark places mixed together.



A Photograph of the Sun. The black spots are Sun-spots; the light areas are faculae.

Then each sun spot is a wonderful thing. All the surface of the sun near the spot seems as if torn and changed, and there are bright, white lines called faculæ running in every direction. The spot itself is changing in a wonderful way. It may be breaking up into little spots, or it may be getting larger than before, or it may be moving swiftly and changing its shape. Surely, something very strange is happening on this great hot globe when spots which are hundreds of times larger than our world can act in this way.

Sometimes astronomers study the sun with the very wonderful instrument which is called a spectroscope. With this they can see what there is near the sun and all around its edge. And here there is seen a wonderful sight. There are great clouds lying above the sun, just as there are clouds around the earth, but the sun-clouds are of a beautiful, deep, red color, and they are many thousands of miles high. Some of these beautiful clouds are called Quiet clouds, because they lie quietly above and around the sun for a long time without changing their shape very much. But there are other deep red clouds which are very different from these. These are great cloud masses which suddenly burst out from the great hot ball of the sun: they are blown out a thousand times faster than a cannon ball is blown out of a cannon. The wonderfully great explosion drives them away to an enormous distance, but afterward they fall back on the sun again.

What is the great sun made of? What are the wonderful clouds which are so beautiful to look at; what is there on the bright surface of the sun, and what is it which makes the sun-spots move and change in so wonderful a way? The astronomers have found out nearly all of these things. They learned them all by carefully studying the light which comes from the sun to us. And when they found what a wonderful thing light is, they learned not only to answer these questions, but also what the stars and many other heavenly bodies are made of, and many other things about them.

WHAT LIGHT IS.

Did you ever think what a wonderful thing light is? Is it not wonderful that when we go out of doors we can look over the country and see trees and hills and a great many other things, some of them many miles away, and that we know just what they look like without ever going near them? And we soon learn that we can never see anything except when it is in the light. If our world should suddenly become a dark world, we would have to walk slowly and feel our way along, and we could not tell what any object was like until we had gone up to it and felt of it.

In the daytime we can see everything very clearly and we can look a long way off because our world is filled with light which is poured out from the sun. But at night we must burn oil and gas and other things so that the light which they give will fill our rooms or streets so that we can see. For we can never see anything unless there is some light falling on it.

It was a long time before men found out what light is. But now they know what it is, and a great many other things about it. They know that all around the earth and the sun and everywhere there is something which we cannot see or feel called Ether. This ether is like a great ocean which reaches beyond the farthest star. All the stars and worlds are sunk deep in this ocean of ether, and they move around in it and through it like little fish moving in the sea.

If you throw a stone into the water, you know how rings of water at once begin to move away in all directions from the place where the stone fell in. These rings are called waves, and if the water is the still water of a little pond or lake, the waves keep moving farther and farther until they reach the bank and are stopped. In just the same way, little waves are going out in every direction from every bright body. They are not waves of water, but little waves in the great ocean of ether. And these little waves move into our eyes, and are stopped by the wonderful nerves which are there, and then we feel that we are seeing.

If we should look right at the sun, then the waves would come straight from the sun into our eyes. When we look at the clouds or at a house, the little waves which make us see come from the sun just the same, but they reach the clouds or the house first and then bound off from these and enter our eyes. These little waves of light bound away from everything they fall on, just as a rubber ball bounds away from a wall when it is thrown against it. And if there are no light waves falling on anything and then bounding away and entering our eyes we cannot see it.

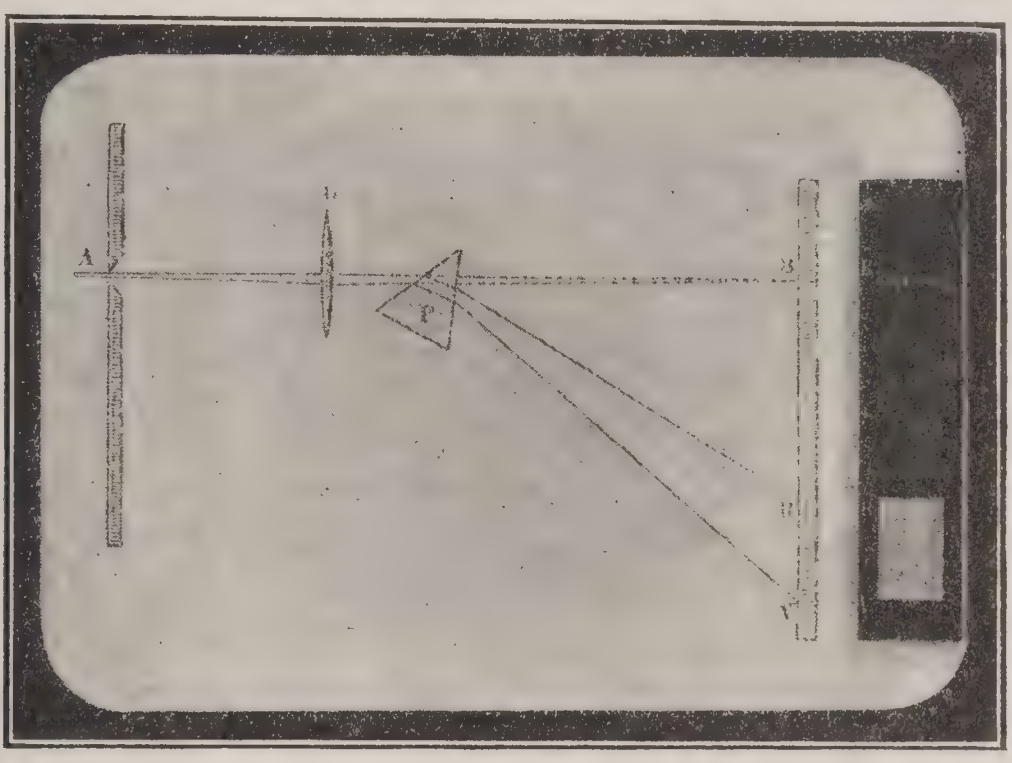
So that now we see why we must burn lights at night, after the sun has set. Every light is pouring out a very great number of little waves, which fall on the books and papers and other things in our room and make it possible for us to see them.

HOW LIGHT OF EVERY COLOR COMES FROM THE SUN.

All the little waves of the ether which move out from a bright light are not of the same size. The waves sent out by blue light are little short ones, and those from a red light are longer. It is better to say that when little short waves enter our eyes, and are stopped by the nerves there, we feel that they are somehow different from longer waves. Just how this wonderful feeling is shown to our brains we do not know, but we know that there is a difference, and we call the first light waves blue and the others red. And there are waves of many other sizes which make us see all the other colors.

If some day you go into a room into which the sun is shining and close the shutters, then if the shutters do not fit tightly together you will see a little beam of sunlight coming through every crack and hole in the shutters, and you can easily see that each beam is exactly a straight line reaching from the crack or hole to the floor or opposite wall. Each little beam seems to be of a white or yellowish-white color, but instead of being really so simple as it looks, it is wonderfully made up of all the colors there are, all mixed together.

To see that this is so you must get a little threesided piece of glass called a Prism. Select one of the beams and look at where its yellowish-white light falls on the floor or wall opposite the shutter. Then hold the prism right in the beam. A very strange thing at once happens. Instead of the whitish light on the floor or wall, you now see a beautiful little strip of bright colors, which is a bright blue at one end and a deep red at the other. The colors that are in the beam of sunlight have been separated from each other so that we can see each of them separately. If you look carefully you may see that the colors which are in the strip are Violet, Indigo, Blue, Green, Yellow, Orange and Red. But the different colors run together, or blend, so that there is no clear division between them.



How Light Forms a Spectrum. The light coming through a slit at A, passes through the prism at P, and is then bent down and makes a little color strip reaching from V to R.

Why is it that a little beam of whitish light which looks so simple is really made up of all these colors, and why does the prism separate them from each other so that we can see them all? It is because what looks to us like white light is really a great stream of little waves in the ether,—little short waves which, if we saw them alone, would look violet, longer ones which would look yellow, and the longest of all which would look red. And when they all enter our eyes mixed together we have the feeling that what we see is white.

When the waves move through the prism they are bent out of their straight path. But the little short or blue waves are bent most and the red ones least. The little waves which rebound from the floor or wall and then enter our eyes from one end of the strip are long ones, so that this end of the strip looks red to us. In the same way the other end looks blue, and in between we see all the other colors.

The beautiful little strip is called a Spectrum. In just this same way we can make a spectrum of a lamp-light, or star-light, or any other light. But the strip will be much fainter, because the light is fainter, and it will not look just like the spectrum of sunlight because the waves sent out by other kinds of light are not exactly like those which come from the sun.

HOW WE FIND WHAT THE HEAVENLY BODIES ARE MADE OF.

For many, many long years men watched and studied the sun and stars and all the other wonderful things which they saw in the sky. They found out how far away many of them are, how much they weigh, and very many other things about them. But they never thought that they would certainly know what these heavenly bodies are made of. All of the suns and worlds around us are so very far away that we do not think that any man will ever be able to go from our earth to one of them. And if we can never get near any of them, how can we ever find out of what it is that they are made?

It was only a little more than a century ago that a wonderful discovery was made. Something new was found out about the little strip of colors which we have been telling about. Men found that by carefully examining it they could sometimes tell just what the bright body from which its light came is made of. And they found out, too, that if the little beam of light had passed through air or any other thing on its long journey to us, they could tell just what it was that it had passed through.

So that then for the first time men learned what the stars are made of. And from the second discovery they found that around many of the stars and around our sun there is a great, heavy, very hot atmosphere, and they found out what this atmosphere is made of too.

Suppose that in front of the prism we place a very thin, little slit or opening. Then suppose that we hold a hot, bright body, such as a piece of red-hot iron, in front of the narrow slit. A narrow little strip of light will pass through the prism from the slit and make a little colored spectrum, just as before. If the iron is now made hotter and hotter, it will get brighter and brighter, and the spectrum will get brighter too, but even if the iron is white hot it will not look very different from how it looked at first. If we heat the iron still more, it will become a very hot liquid, like water or very bright milk, and if we make it still hotter it becomes what is called a gas, like the gas we burn or the air we breathe, only the gas will be a gas made of very hot iron.

Just as soon as the iron becomes a gas, a great change is seen in the spectrum. Instead of the colors all blending together, it will change into a spectrum made up of a great many bright little lines or bands, each separated from all the others. And always when iron is made so very hot that it becomes a gas, its spectrum will look exactly this way, whether the iron is on the earth or in a star or on the sun. And no other thing except iron can ever make a spectrum which has exactly the same lines in exactly the same position.

In the year 1882, a great comet appeared. As it moved along in its path it got very near the sun where it was very hot. When a prism and a very narrow slit were then placed so that its light made a little spectrum, the spectrum was seen to be partly made up of exactly the same bright lines that belong only to very hot iron. So we are sure that, among other things, that comet was made out of iron, and at the time when its spectrum was studied the iron was very hot.

Iron is not the only thing which we can find in this way. Every different thing in the whole world, if it is made hot enough, will become a bright gas, and its spectrum, which will be made up of little bright lines, will be different from any other spectrum. So that if that thing is in any of the stars or in the sun we can find out that it is there.

The first great discovery about light, which men made fifty years ago is this:

Every different thing there is will become a bright gas if it is made hot enough: if we then use its light to make a spectrum this spectrum will be the one which belongs to that thing, whatever it is, and it cannot be made by the light from anything else.

A WORLD HOTTER THAN THE HOTTEST FURNACE.

When we arrange a slit and a prism so that we make a spectrum with the light from nebulas and stars, as we have just told about, we may see thousands of bright little lines, all in their exact places, so that we know at once just what things these nebulas and stars are made of. And we know that all these things are so very hot that they have become gases and throw out a bright light.

Suppose that we make three little color strips, one from light which comes from our sun, one from light which comes from a bright yellow star like Capella, and one from the light of a deep red star. We will see that crossing each of these little color strips there are very many black lines, but that there are not any bright lines as there were before. The lines from our sun and from Capella look just alike, but those made by the red star are very wide and dark. It has been found out what all these black lines show; they show that the little beam of light has passed through a region of gas. For it has been found that if at any time a beam of light passes through any gas, this gas will make black lines in the spectrum. If we should see that the black lines are in just the same places that the bright lines made by iron gas would be, then we would know that our little beam of light had passed through iron gas. And when the lines are wide we know that ocean of gas is very deep and heavy.

The great, round ball of our sun is wonderfully hot and bright. Nowhere on the earth, not even in the middle of the fire of the very hottest furnaces, is it nearly so hot as it is on the sun. Let us see what would happen if our world should draw nearer and nearer to this great hot star. We need not be afraid that it will ever do this, for it is known that it will never be much nearer the sun than it is now nor much farther away; and it is indeed well for us that this is so.

But let us suppose that our world has started out on this long journey. Very soon it would begin to grow uncomfortably warm. Before long we would feel all over the earth a heat greater than that of the hottest days in summer. All the ice and snow of the Polar regions would melt, and near the Equator it would be so hot that no one could stay there. As we got nearer the great central furnace, all the trees and grass would be killed, and soon no living thing would be left on all the earth. Then, as it grew hotter and hotter, all the waters of the oceans and seas would be turned to steam and hang in great clouds around our world.

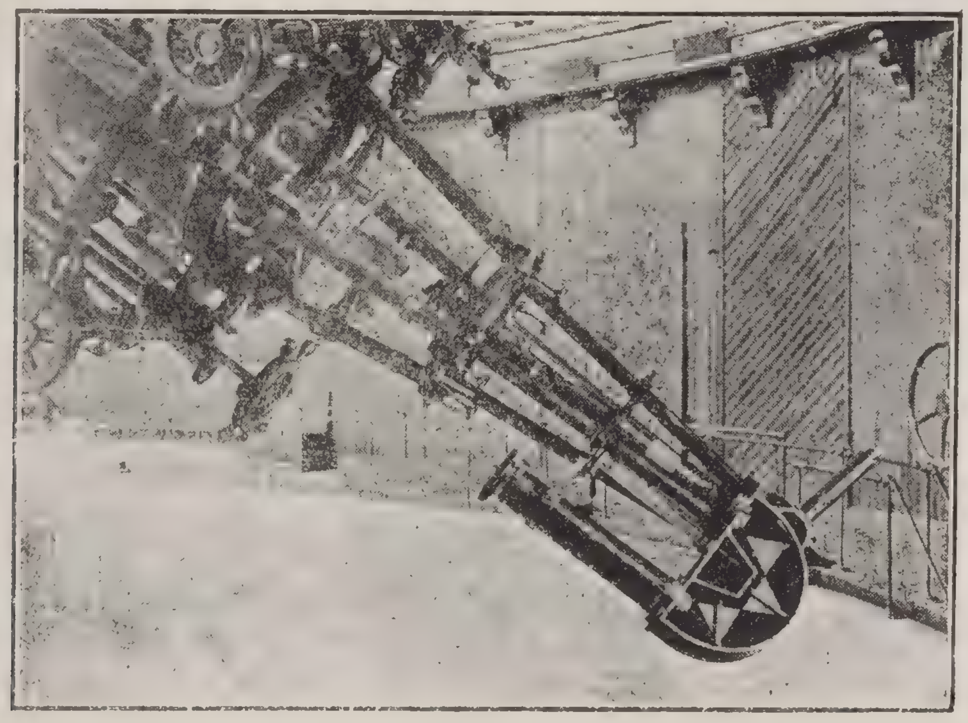
The sun is so hot that all this would happen while we were still many millions of miles away from it. But if our world kept on drawing nearer, then it would truly be altogether destroyed. Even when we were as far away from the sun as the moon is from us, all the rocks and earth and metals and everything on our world would have gotten red hot, and then white hot, and then melted, and long before we had nearly reached the surface of the sun, our whole world would be changed into nothing but a mass of hot and glowing gas.

Near the sun and all around it in every direction there is a great mass of just such very hot gas. It is kept there by the pull of the sun, just as the pull of the earth keeps our own air near the earth. The sun is in the center of the cloud of gas: it is because the very bright light from the sun must pass through this gas on its way to us that we see the black lines in the spectrum.

When we study the little black lines, we find out that the gas around the sun is very different indeed from the light, cool gas, or air, which is around the earth. We find that it is made partly of heavy metals, such as Iron, Copper and Lead, and partly of the same things that the stones and rocks of our earth are made of, such as Calcium, Magnesium and Sodium. And there are many other things in the atmosphere of the sun. All of them except one are found on our earth too. On our earth they are most of them heavy, cold earths and rocks and metals, but around the sun they are changed into gases by the great heat and form a strange and wonderful atmosphere.

HOW ASTRONOMERS STUDY SUNLIGHT.

When a great telescope is arranged to study the light which comes from the sun or from a star, we must have a very narrow slit near its smaller end where the image is formed, and back of this there must be a prism. Then, if the telescope is pointed to the sun, all the light which falls on the big glass lens at the upper end comes down through the tube, and much of it passes through the very narrow slit. Instead of going through only one prism, it next goes through many prisms, which are all placed inside a round, dark box so that no other light can pass through them. When the light goes through many prisms in this way, the color strip is much longer than if it went through one, so that we can see it more clearly and study the position of the lines which are in it much better.



A Spectroscope as used with a Telescope. All the light passes through the three prisms and then up through the little tube which is below and to the left. A photographic plate is at the upper end of this tube.

If we should hold a piece of glass or a sheet of paper near the prisms we would see on it the little color strip made by all the prisms. But instead of this, a little photographic plate is put at this place and a perfect little photograph of the color strip and its lines is made. It is in this way that the photographs of spectrums are always taken.

A large telescope makes everything look so much larger that when you look through it you cannot see all of the sun at once. You can only see a little piece of the sun at one time, and the little photograph which is made is a photograph of the color strip made by the light which comes from just the little piece of the sun at which the telescope is pointed.

WHAT IS FOUND ON THE SUN.

We will now suppose that we have pointed our big telescope at different places all over and around the sun and taken a little photograph of the color strip made by every part, and we will study the little photographs to see what they tell us.

In the first place, all the pictures made from light which comes from the wonderfully bright, round ball of the sun will look very much alike; they will be little color strips crossed by a great many black lines. From this we know that all around the very hot ball there is an atmosphere, which, though very hot, is cooler than the ball itself, and that the light which has come into our telescope and made our little photograph has had to pass through this atmosphere. The position of the black lines shows us that in this atmosphere there is very hot iron and lead and carbon, and very many other things.

If we point our telescope near the bottom of a great red, explosive cloud, the little picture will show us that there are here the same things; the explosive cloud is made out of all the very hot, heavy things which were driven out from the great ball of the sun more violently than ever the swiftest cannon ball was shot out of a cannon.

But if we make the little picture with light which comes from the upper part of one of these beautiful red clouds, or from light which comes from one of the quiet clouds, it will look very different. The color strip will then be crossed with bright lines, and this shows us that the light which has come to us has not passed through any atmosphere or gas. And from the position of the bright lines in the color strip we learn that the bright red clouds are made out of two kinds of gas mixed together. One of these is a very light gas called Hydrogen. This gas we often use on our earth; it is so very light that balloons are sometimes filled with it when we wish them to go up very high. Mixed with hydrogen gas in the great cloud there is another gas, even lighter than hydrogen, which is called Helium.

WHAT WAS FOUND ON THE SUN BEFORE IT WAS FOUND ON THE EARTH.

For many years astronomers studied the little color strip photographs made by sunlight. They found that some of the little lines are just like those made by very hot iron on the earth, so that they knew that the sun was partly made of iron. And they found that nearly all of the rest of the lines were just what could be made by heating the rocks and earth and metals of our world very hot, and so they knew that nearly everything which the sun is made of is found on the earth too, only on the sun everything is so very hot that it is turned into a bright gas.

But there were some lines in the photographs that they could never get from the light of anything on the earth. They called the unknown thing which made these lines Helium, and they said that although the sun is made out of almost the same things as our world is, yet there is one thing on the sun that we have never found anywhere on the earth. In some of the stars and nebulas this strange, unknown Helium was also seen.

Many years later, a man was studying some curious, velvety-black rock which is found in Norway. He found that the rock was made out of many different things, some of which are very rare on our earth; but most interesting of all, he found that in the rock there was a new thing,—something which no man had ever found on the earth before. And when he made the color strip of this new thing to see what its spectrum would be, he was astonished to find that its lines were exactly like the Helium lines which men had been photographing in the sun for twenty-five years! So that then for the first time men knew that there was some helium on the earth.

It is a wonderful thing that we can find out what our great hot sun is made of. But is it not even more wonderful that we could know how on that far distant world there was something that we had never found on our own world; something that was not found here until twenty-five years after it had been found on the sun?

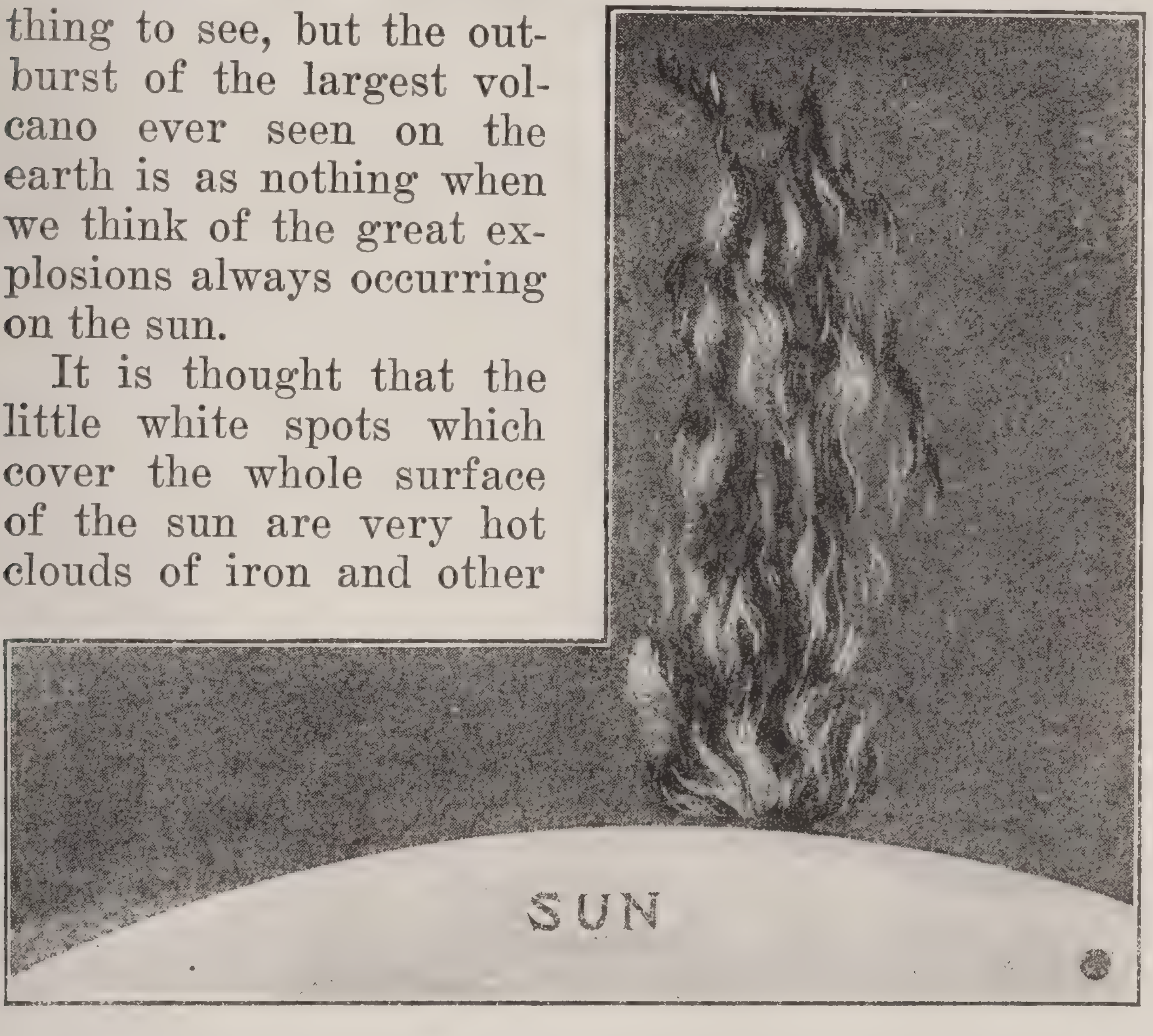
A WORLD WHICH IS NEVER AT REST.

From what has been said we have learned that the sun is a very great ball, so very hot that nothing on it can be solid or even liquid, but that everything is turned into a very bright gas. The bright outer part, which is all that we can see, is hotter than any heat that we can ever make on the earth. We know that inside the ball, below the outer surface, it must be very much hotter yet: how wonderfully hot it is there no man can tell.

Everything throughout this great ball is forever moving and changing with terrible swiftness. Streams of very hot matter are rushing from the inside to the surface, great streams which would sweep whole worlds like ours along with them as easily as rushing streams of water on the earth carry little chips upon their surface. When this matter reaches the outside it must grow cooler, and after a time it must again find itself inside the ball, only to be again heated and to rush out as before. So that everything throughout the sun is always in very swift and ceaseless motion.

Sometimes the matter rushing out is moved so swiftly that it is shot high above the sun and we see it as a great red cloud, bursting outward with terrifying swiftness. On our earth, volcanoes sometimes pour out great clouds of hot gases and melted rock, and bury whole cities under a rain of fire. This is a wonderful and terrible thing to see, but the outburst of the largest volcano ever seen on the earth is as nothing when we think of the great explosions always occurring on the sun.

It is thought that the little white spots which cover the whole surface of the sun are very hot clouds of iron and other things, which float in the still hotter gases around them. These clouds are one hundred or two hundred miles across. Sometimes when we are looking at a part of the sun like this, we see a great change beginning to take place. In some parts the whole surface is pushed up from below, and it then looks very bright. In others, little black spots begin to form, and these by and by run together and grow larger until a great sun-spot is made. Clearly, some-



One of the great Eruptions at the edge of the Sun. The little, round, black Dot shows how the Earth would look if it were placed near the Sun's bright Disc.

thing is greatly disturbing this part of the sun. Some astronomers think that when we see a sun-spot, it shows that there the surface of the sun is caving in: that a great deal of very hot matter has rushed out from the inside of the ball, and that matter on the surface of the sun is falling down to take its place, just as we often see the surface of the ground cave in to fill a hole. Others think that every sun-spot is a wonderfully great storm, very like a cyclone on our earth, but far greater and more violent than any cyclone that we can think of.

It is a very strange fact that the great disturbances which make sun-spots do not keep up regularly all the time. Once every eleven years we see the most of the wonderful changes which occur on the sun, and then there are more sun-spots and larger ones than before. And at this time the surgings and explosions going on in the sun send out waves of electricity all the way to our earth. There are then many electrical storms on our world, and the beautiful Northern Lights, which are made by the electricity in our air, are brighter than at any other time. All this will happen the next time in the year 1916.

CHAPTER VI.

Mercury, the Smallest World.

HOW A NEW WORLD WAS SEEN, MANY AGES AGO.

THOUSANDS and thousands of years ago, when perhaps even the first of the Indians had not yet come to America, and when all over the whole world except in one little corner there lived no one but savage people, some man must have discovered a new star. Perhaps he was a shepherd of Chaldea; perhaps one of the people who lived in Egypt long before the nations who were to build the pyramids had been born.

We can imagine this man, soon after sunset, when the sheep have all lain down for the night, going to his tent to sleep. But before going inside, he stops for a short while to look at the wonderful heavens so full of stars, which forms a great dome above him. He must have seen them all many times before. Doubtless he knew each of the bright ones by a name, and he knew the shapes of all the curious star figures and had names for these too, though they were not the same names that we know them by.

All at once he sees a very surprising thing indeed. Low down in the West, in the beautiful sunset glow, there shines out a star which he has never seen before. He looks again. Though it is so near the ground there can be no mistake: the new star is almost as bright as the brightest star in the sky. No doubt he calls the other shepherds and tells them about it, and there they stand watching this bright little visitor until it sinks below the ground.

On the next evening they are watching the western sky again to see if the new star will still be there. And soon after sunset they see it, shining out more brightly than ever, but still low down near the ground. There they see it for many evenings, but they soon notice that it is getting harder and harder to find. This is not because it is getting smaller, for it is still as bright as ever, but because it seems to be drawing nearer to the sun. At first it was so far on one side of the sun that it did not set until more than an hour after sunset. But a few evenings later it followed so closely after the sun that they could only catch sight of it, lying almost on the ground, for a few minutes after sunset, while the whole sky was still flooded with sunlight and before many of the other stars could be seen. And soon after this they could not see it any more at all.

We can imagine how they must have talked about the strange new thing. Ever since they were little children they had seen the other bright stars. Night after night and year after year through all their lives, these were always the same. How very different was this new star which only seemed to last a few days and yet which looked just like any other star. Would they ever see it again, or had it gone forever?

We do not know how long they watched for the little body or when they next saw it. Perhaps they looked for it for several weeks and then grew tired. Perhaps it was many years before they found it again. But we do know that in just sixteen weeks and four days after it was first seen, there is was, shining out in the West just as it did before. Every sixteen weeks from that early time until now, the bright little star appears in the West, moves a little distance from the sun toward the East, and then draws near the sun again and is lost to sight.

HOW MERCURY CHANGES FROM AN EVENING TO A MORNING STAR.

In just the same way that men found a bright star shining in the West just after sunset, so they saw many ages ago that sometimes a star shone out for a few days in the East just before sunrise. The little star in the East acted in just the same way as the one which was seen in the West. It would draw farther and farther away from the sun for a few days, each day rising a little longer before sunrise and being seen more easily, and then it would draw near the sun again, until soon it could not be seen at all.

We know that these two stars which always stay so near the sun are really only one star, but it was a long time before men found this out. The Greeks called the evening star Mercury and the morning star Apollo, but they did not know that Apollo was nothing but the little evening star, Mercury, when it had moved to the other side of the sun. And we know, too, that the one little star which we now call Mercury is not a great hot star at all, but only a little cold world which is not quite half so large as our own world is.

The little world called Mercury goes around and around the sun just as our world does, but because Mercury is very much nearer the sun than we are its path is much smaller. Suppose that we could see Mercury in the daytime, and suppose that we could see its path too, like a little, bright ring around the sun. Then whenever you looked at the sun in the sky you would see the little path around it, and you would see the little world going slowly along the path. All day long as the sun moved over the sky it would carry the little ring and the world along with it. The path is really almost a circle, but it would not seem so because it is turned almost edgewise toward you.

Suppose that Mercury is just at the left hand edge of its narrow path and that the sun is almost setting. Then, as the sun is sinking toward the ground, it is clear that the sun will set first and Mercury afterward, so that then you will see Mercury in the evening after sunset. In a few weeks Mercury will have reached the point of its path just below or above the sun, and then it will set just when the sun sets. But it does not get very dark until quite a little while after sunset, and as we cannot see Mercury while it is still bright daylight, we would really lose sight of it many days before it reached this point.

In just the same way, when Mercury had reached the point of its path which is farthest to the right of the sun, it would set before the sun set, and as it is then on the right hand side of the sun, we would see it rise before sunrise in the morning. It is only when the little world seems farthest away from the sun that it can be far above the ground when the sun is below the ground. So that we can only see it for a few days when it is near the points of its path which are farthest east or west of the sun.

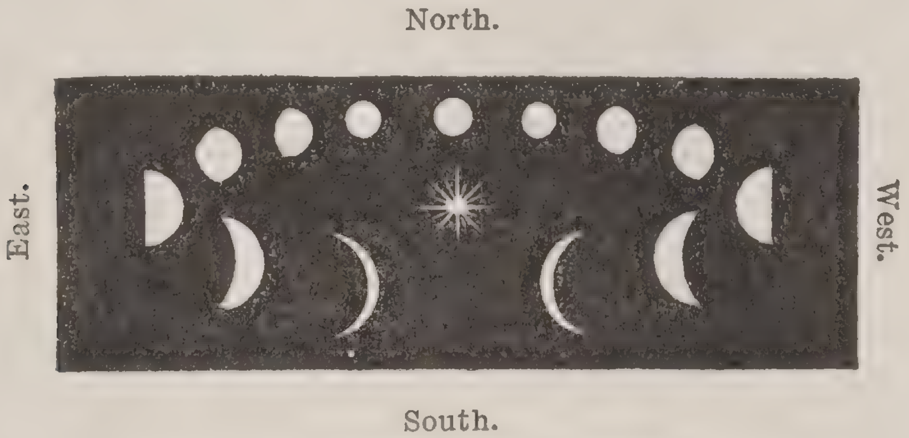
Although we cannot see any such bright little ring around the sun, we can think of how the little world is always going slowly along in its path just as if we could see it. When we look at the sun in the sky we can think how Mercury is there near the sun and always going around it, although the sun is so very bright that we cannot see it until after the sun has set. And we can imagine to ourselves how the little world must reach the left edge of its path and be seen in the evening, and how then it will go on to the edge of its path which is farthest west and be seen in the morning, and how after this it will be lost to our sight as it passes the sun until at last it reaches the left edge of its path again and is seen as an evening star.

WHY MERCURY LOOKS TO US LIKE A LITTLE MOON.

If you could look at this little world with a telescope, there is one thing you would see right away.

You would say, "Why, it looks just like a little moon: it is not round!" When you happened to look at it, it might look nearly round, or it might look like a half circle, or it might be the very narrowest little crescent, just as the moon is when we see it low in the West in the early evening.

These beautiful changes are made because Mercury is a dark world, just as our earth is. If the sun did not shine on it we could not see it at all, and we never see any part of it except when that part is in sunshine. But because Mercury is a round world the sun can only shine on one-half of it at a time; the half which is turned away from the sun is in darkness. It is just the same way on our earth. On one half of our world the sun is always shining and on that half it is day, but the half of the world which is turned away from the sun is in darkness and there it is night.



How Mercury looks as it moves around the Sun.

Let us now think of Mercury going around and around the sun in its little path, and we will remember that it is only the half of Mercury which faces the sun that is bright. When Mercury seems passing above or below the sun as it moves along that part of its path which lies beyond the sun, then we who are on the earth will look right past the sun at Mercury and see all of the little world which is in sunshine. But when it has reached its farthest point east of the sun just one half of what we see is in sunshine and the other half is in darkness. We cannot see the dark half at all, so that then Mercury looks to us like a half circle. And still later, when the planet is nearly between us and the sun, almost all of the part which is in sunshine is turned away from us. We can look just a little way past the edge of the dark half and see a narrow little strip of the part which is in sunshine. This is all that we can see, and it will look to us like a beautiful, narrow, little crescent.

It is very easy to arrange a pretty little experiment to show why the shape of Mercury seems to change. First, on some evening put a bright lamp on a table at one end of a room. Then ask some one to move a round ball, such as a tennis ball or a base ball, around the lamp, just as Mercury moves around the sun. Then if you sit at the other end of the room, you will see how one half of the ball is lighted up; that is, if you think of the lamp as a sun, it is day on one half of the ball and night on the other half. When the ball is moved around the lamp the shape of the lighted part which you can see will change from round to a half circle and then to a narrow little crescent, exactly as we see Mercury changing as it moves around the sun.

WHAT IS SEEN ON MERCURY WITH A LARGE TELESCOPE.

Mercury is so small a world and so very near the sun that even when the most skillful astronomers look at it with the largest telescopes they can see very little of what there is on it. Sometimes they can see faint little shadings, which may be great plains or even mountains, but what they are we do not know because we cannot see them clearly enough to find out. But by carefully watching the little dark shadings one very remarkable thing has been discovered, and that is how long it takes the little world to turn around.

If we could stand on Mercury and look at our earth, we would see large, dark markings on it made by the great continents, and all over the polar regions we would see a very bright white part where the ice and snow never melt. The great seas of the world would probably look to us like large shadings of a dull gray or greenish color. If we should watch this interesting world for only a little while we would see that it is turning around and around very fast; each marking would be brought into view at the left hand edge and be carried all the way around to the right hand edge in twelve hours. It would take us only a little while to find out that the great round world which we call the earth is turning entirely around once in every twenty-four hours.

But the little shadings on Mercury do not act in this way at all; even if we watch them hour after hour we can hardly see that they have moved. It is at least clear that the little world does not turn around so fast as our world does, and from very long and careful watching astronomers have decided that one half of Mercury is always turned directly toward the sun and that the other half is always in darkness. This is a very strange world indeed: a world where the sun never rises and never sets; a world on one half of which it is always day and where on the other half it is always night.

Mercury is a dull-looking little world when seen in the telescope. Sometimes Venus seems so near it in the sky that we can see them both at once very near together and then Venus shines like bright silver while Mercury is only as bright as lead. From this we think that there is very little air around the smallest world and that there are no clouds there. For when our own clouds are in sunshine they are beautifully bright, sometimes shining like silver as the clouds around Venus do; but on Mercury nothing like this is seen.

From measures of this little world we find that it is only three thousand and thirty miles through, so that it would take nearly eighteen Mercuries to make a world as large as ours. And the little planet spends eighty-eight days in going all the way around its path, so that a year on Mercury is only eighty-eight days long—which is only a little more than a quarter as long as our year is.

A JOURNEY TO THE SMALLEST WORLD.

Let us imagine that on some evening when Mercury is shining brightly in the West we set out to pay a visit to our little neighbor. We must in some way fly up through our air, higher and higher, until our earth looks only like a round, bright ball behind us. Then we must push on through the great ocean of ether, where no air is, for millions and millions of miles, until at last we land on the new world which we have come to see.

But how shall we go? It must be on something that can travel very fast because the journey is a very long one. Shall we take the fastest express train? This will hardly do, for even the fastest train would require more than two hundred years to make the journey. Let us imagine that we can take passage on the swiftest cannon-ball, and even then our ride will not soon be over. For after the shot which bears us has been fired, more than seven years will pass before we finally fall upon the little planet.

However, let us imagine ourselves on a cannon ball and rushing along on our journey with wonderful swiftness. For a very long time we could see but very little of the new world to which we are going. As the years passed away it would grow brighter and brighter, but it would not be until the very last year of our journey that we would be close enough to it to see that it was round. Until then it would look to us like a very bright star; that is, just like a point of very bright light.

Just as the last year of our long journey was beginning the bright little star would begin to look like a very small, round circle. As we drew nearer it would seem to grow larger and larger, but it would grow very slowly; not until ten days before our journey was to end would the new world look to us as large as the moon looks when we see it from the earth. But during those last ten days the planet would seem to grow with such terrifying swiftness that in a very short time it would seem to fill one half of the whole sky. Soon after this all its hills and valleys would be clear to us and we would find ourselves dropping from an immense height onto a land which stretched beneath us in every direction as far as we could see.

THE LAND WHERE IT IS ALWAYS DAY AND THE LAND WHERE IT IS ALWAYS NIGHT.

After so long a journey let us stay on the new world a long time before starting back again to our earth-home. Let us explore for a whole year, but we will let our stay last only for a Mercury year instead of for an Earth year. On the world where we now find ourselves a year is only 88 days long, but we will find that a visit of only three months will be quite long enough. For unless we can bear intense heat, ten times hotter than we ever know on the earth, and great cold too, and unless we can live without breathing or eating or drinking, we cannot remain in the new world at all. But let us imagine that we have been changed into wonderful creatures who can do all this; and now we will start out to make discoveries.

First, we notice how very light we feel. We can jump over a man's head easily, and we proceed over the rough country, running up and down steep hills and taking steps six feet long without growing at all tired. This is because the little world which we are now on pulls us down so much less strongly than our earth that we only weigh one half as much here as we used to do.

If we have descended on the sun-lit half of our new world, that is, on the half where it is always day, we will see a great sun pouring its heat and light upon us; a sun which because we are so much nearer to it looks seven times larger than when we saw it from the earth. The intensely bright light hurts our eyes, but behind every hill and rock there is an inky-black shadow, for as there is very little air on our new world all shadows are much blacker than they are on the earth. But strangest of all, the great hot sun neither rises nor sets. It is fixed motionless in the sky, and hour after hour it pours its heat down upon us from exactly the same place in the heavens.

Let us leave this too hot side of our little world and go to the side where it is always night. As we walk along we see no seas or rivers or any water at all; if a sea or lake could be placed on this part of Mercury the great heat of the sun would soon cause all of its water to disappear. As we go forward we see the sun sinking nearer and nearer to the ground, and soon it disappears entirely and we have reached the night side of this strange little world.

Instantly we see the whole sky filled with stars. Among them there is one quite bright star, but not the brightest star of all, which we look at with special interest. This star is the far distant earth from which we have come. We see no moon in the sky, because our new little world has no moon, but very near the bright earth-star we can see another little star only about one-fiftieth part as bright. This little faint star, so near the earth-star, is the moon which goes around our earth.

If before we were too hot, we are now very much too cold. In this land where the sun never rises perhaps the ground is always covered with snow. Perhaps there is some air around the smallest world, and if there is then the most violent wind storms must always be raging. For when the air on the day side is heated it will rush up and pour over the cold air on the night side; the cold air will thus be forced over to the day side, to be heated in its turn and in its turn to rush back to the night side again. So that if there is any air at all, a hurricane of very cold wind must always be blowing from the land of night to the land of day. If there is no air, then everything is perfectly still; from age to age no change will ever be seen either in the land of day or in the land where it is always night.

A YEAR ON MERCURY.

If there is any air on Mercury it is just possible that there is one place where we could live without being killed by the great heat or frozen by the cold. This is near the line around the planet which divides the bright half from the dark half. Let us find a place in this little strip where we can be sheltered from the terrible wind which is always blowing, and remain here for the rest of the Mercury year.

We have seen that just one half of Mercury is turned toward the sun, but this is not quite true. The world turns a very little from side to side, so that the line between day and night may move six hundred miles back and forth from the place where it would lie if exactly the same half of Mercury was always turned toward the sun. If we were in this little strip we would see the sun slowly rise a very little way above the ground and then sink back again. To us who are accustomed to seeing the sun moving around the heavens this would be a very curious sight, but we would be even more surprised by the changes which we would see in the size of that body.

The path of Mercury around the sun is not a perfectly round circle, but a flattened curve called an ellipse. The sun is very far from being at the center of this path; when Mercury is nearest the sun it is fifteen millions of miles nearer than when it is farthest away. If we arrived on Mercury when the planet was at its greatest distance from the sun, we would see that the sun seemed each day to be growing larger and larger. By the time the planet had drawn nearest the sun we would be so near that it would look to us more than twice as large as at first. And it would pour down upon us twice as much heat and twice as much light as when we first saw it.

It takes Mercury eighty-eight days to move entirely around in its path. The times of greatest light and heat are therefore just eighty-eight days apart. These would only be noticed by one who was on the sun-lit side of the planet. If one were on the dark side he would never see the sun nor feel its heat and he would not know whether it was the season of greatest heat or not. But if there is any air on Mercury he could at once tell when the world was nearest the sun, because the winds would then blow with a much more terrible violence than at any other time.

TRANSITS OF MERCURY.

Generally our earth is in such a position that if we could see the path of Mercury it would look like a narrow curve, or a very much flattened hoop. But sometimes we see it almost exactly edgewise and then it looks almost like a straight line passing right through the round sun. If at such a time the planet is moving through the part of its path which lies across the sun's disc we will see it between us and the sun, and then there will occur what is called a Transit of Mercury.

At the time of a transit of Mercury if we look at the sun with a telescope we will see a round, perfectly black little dot move onto the bright sun and pass slowly across it. If we see the little world cross the sun just at its center, the transit will last about eight hours, but if the little dot moves across the bright sun near its upper or lower edge its passage will take a much less time. Some astronomers have thought that they saw a little ring around the black looking planet when it was in line with the intensely bright sun, and that this shows that there is an atmosphere around the little world. Others say that the little dot is always perfectly black and round, without any sign of an atmosphere at all.

On November 7, 1914, at two minutes past five o'clock in the morning (Eastern Standard Time), the little planet will be seen to move onto the sun near its lower edge. Four hours later, at seven minutes after nine o'clock, it will move off the sun and be lost to sight. People in the United States and Canada cannot see the beginning of this transit because the little dot will move onto the sun before sunrise. When the sun rises they will see that the planet has already moved half way across it, but they can watch the last half of the interesting sight and see the planet leave the face of the sun.

After this there will not be another transit until May 7, 1924. At this time the planet will pass almost exactly across the sun's center. It will be seen to move onto the sun at nineteen minutes before four o'clock in the afternoon and will pass off the sun at twenty-seven minutes past midnight the next morning. To all persons in the United States and Canada the sun will be set before the transit is over so that they can only see the beginning of it.

CHAPTER VII.

Venus, Our Sister World.

A PLANET WHICH IS SOMETIMES NEAR THE EARTH AND SOMETIMES FAR AWAY.

WE have seen how, very near the sun, there is the strange little world called Mercury, which rushes along so rapidly in its path that it goes all the way around the sun in only eighty-eight days. And far outside of this there is the earth on which we live, moving so much more slowly along its very much larger path that it requires three hundred and sixty-five days to pass all the way around it. Almost exactly half way between these two worlds is the beautiful planet Venus, a world which is always moving around and around the sun just as Mercury and the earth do.

Of all the worlds which are moving around our great sun as a center this world is in many ways the most interesting to us. In the first place it is our nearest neighbor of them all, for when nearest the earth it is only half as far away as either Mercury or Mars, which are our next nearest neighbors. Then, too, it is more nearly like our own world than any other body which we ever see. It is almost exactly as heavy and of almost the same size; it seems to be just about as warm as our world is, and most interesting of all, it is covered by an atmosphere which, as nearly as we can tell, is very much like our own. If among all the planets there is a single world on which we could live, it is probable that Venus is this world.

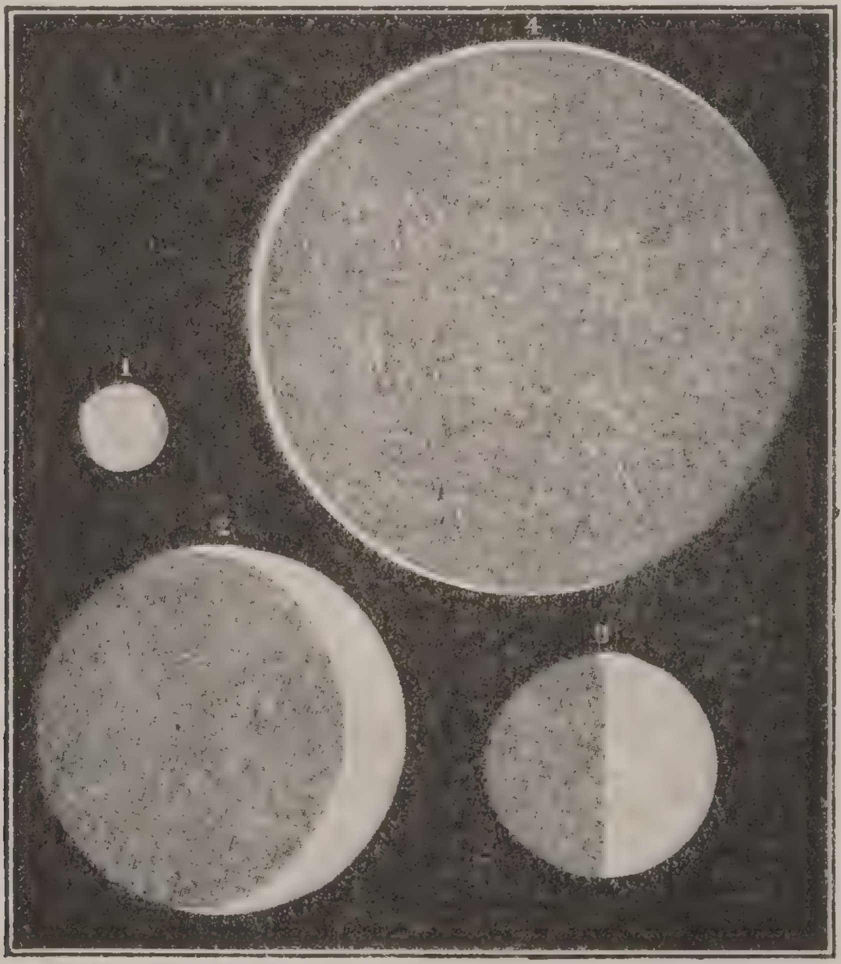
If when we look at the sun in the sky we could see the path of Venus lying around it, it would look very much like the path which Mercury follows. But the path of Venus is so very much larger that it would seem to stretch half way across the sky. When the planet seemed farthest away from the sun, at the right hand or east edge of the path, it would sometimes set so long after sunset that we could see it shining in the western sky until ten or eleven o'clock in the evening. And in the same way, when it had reached its greatest distance on the other side of the sun, it might rise more than three hours before sunrise.

The real shape of the path is almost an exact circle lying just inside the round path of the earth, and this is why Venus is sometimes so much nearer the earth than it is at others. When the planet is nearest the earth it is only one-sixth as far away as when it is in the part of its path which is beyond the sun and exactly on the other side of it. If we could see it clearly when it is so near us, it would look larger even in a very small telescope than the moon does to us when we look at it without a telescope. And with a large instrument we could find out a great deal about our sister world. But it happens that when Venus is very near us we can see very little, because the part of the world at which we are then looking is in darkness.

WHY THE SHAPE AND SIZE OF VENUS SEEM TO BE ALWAYS CHANGING.

Like Mercury, Venus is a dark world which we can only see because the sun is shining on it. It looks like a little moon and seems to change its shape just as Mercury does. Venus is so large and bright that it is a most interesting and beautiful sight to watch it go slowly through its changes, a sight which can be clearly seen even with a very small telescope.

If we look at our sister world when it is farthest away from us we will see the sun-lit half of the planet and Venus will appear to us as a bright, round, little moon. When it has reached its farthest distance to the left of the sun, one-half of the world which is turned toward our earth is in darkness and the other half is bright, and then it will look to us like a moon which is half full. As it seems to draw nearer to the sun, the sun-lit part will become more and more turned away from us until finally we see nothing but the narrowest imaginable little silvery crescent. And when the world is between the sun and us, and is passing from one side of the sun to the other, we will be looking at the half of the planet on which there is night, so that we can see nothing at all.



How the shape of Venus seems to change. When farthest away it is like the picture numbered 1. When almost between the earth and Sun it looks as shown in 4.

If we watch the planet as it moves around in its path, we will see that its size seems to change in a very striking way. When this world is on the opposite side of the sun from the earth it is so far away from us that it looks very small in the telescope. But as it draws nearer it seems to grow steadily larger until it looks more than six times as large as it did when farthest away. It is at this time that we see it only as a very narrow crescent.

WHEN VENUS IS AN EVENING STAR.

When Venus is far to the left of the sun it is a wonderfully bright and beautiful star. At this time it shines out for many weeks, the brightest of all the stars in the sky. Sometimes when the night is very dark and the moon is not above the ground its light is so strong that we can even see faint shadows of various objects which are made by Venus-light. At these times when Venus is high up in the west after sunset many people who know very little about the wonderful heavens see it there and wonder what the bright light is. They write to the newspapers and to astronomers and ask if someone west of them on the earth has not each evening been sending up an electric light in an air-ship or balloon. This question interests them very much, but if they only knew about it, how much more there is of interest about the wonderful world which they really see.

Our sister world will shine thus brilliantly in the west in February, 1913; September, 1914; April, 1916; November, 1917; July, 1919; February, 1921; September, 1922; and in April, 1924. Just nineteen and one-half months after it is a bright evening star we will always see it again in the evening sky.

Every five months after Venus has climbed to its highest point in the western sky we may always see it high in the east before sunrise. It is then no less bright and beautiful than when it is an evening star, but not nearly so many people see it in the morning because there are few of us who often get up in time to see the sun rise. Yet the wonderful beginning of a new day is always a most beautiful sight. If we go out of doors before dawn we will at first see all the heavens covered with their multitude of bright stars, which are very slowly and steadily climbing upward in the east and sinking toward the ground in the west. But as we look we see the very faintest, most delicate, silvery light beginning to fill the eastern sky and soon this becomes so bright that we can no longer see the fainter stars there. At this time the whole western heavens are still filled with stars. But the beautiful pale light covers the sky more and more until only the brightest stars can be seen. It is then that low in the east the most brilliant Venus appears, the forerunner of our sun, and long after the other stars can no longer be seen this beautiful world shines out in the dawn, until at last the slow turning of the great sphere around us brings the sun itself above the ground, and a new day has begun.

This birth of a new day, the wonderful miracle which we may see over and over again all our lives long, has always filled the hearts of men with its beauty. Great poets have sung of it, but the song of the greatest poet of all is the most beautiful:

> "Lo! here the gentle lark, weary of rest,
> From his moist cabinet mounts up on high,
> And wakes the morning, from whose silver breast
> The Sun ariseth in his majesty;
> Who doth the world so gloriously behold,
> The cedar-tops and hills seem burnish'd gold."

HOW WE KNOW THAT THERE IS A DEEP ATMOSPHERE AROUND OUR SISTER WORLD.

All around our own world there is an atmosphere which covers everything on our earth and extends very far above us. Everything on our world, even the very highest mountains, are sunk deep in this ocean of air and we are always at the very bottom of it. This ocean which always covers us is nearly one hundred miles deep, and though it is mostly made out of air it also has a great deal of water in it, which we often see as clouds, and also a few other things.

All these together are called the atmosphere of the earth.

If all the air should be taken away from our world, no plants would grow, no fire would burn, and we ourselves and all the animals could no longer breathe, and would die. When we look at the other worlds, so far away from us in the heavens, one of the most interesting things about them and one that we most wish to find out is whether they have an atmosphere too; for if they have none we cannot see how anything can live on them. With the little world Mercury, we found that we do not certainly know whether it has an atmosphere or not, and when we come to tell about the planet Mars we will find that for many years astronomers have been studying this world to find out what kind of an atmosphere it has.

But that our beautiful sister world Venus has a deep atmosphere which covers every part of it there is no doubt. When the planet is almost between us and the sun, so that the sun-lit side, or the half of the world where it is day, is almost all turned away from us, we can see the atmosphere brightly lighted up by the sunlight which falls on it. The atmosphere, shining in the sunshine, has been seen lying all the way around the planet. Sometimes too, Venus passes across the bright face of the sun and then all around the round, black ball of the planet we can see a bright little ring of light which we know is its atmosphere lighted up by sunlight.

All of us who are on the earth have many times watched the beautiful sun as it sank below the ground in the west. We know that it is the bright sun shining on our world that makes our day, but we have noticed that just as soon as the sun has gone from the sky it does not become night. Instead of this it slowly grows darker and darker, and not until an hour after we can no longer see the sun does it become perfectly dark. This is because of the great ocean of air which surrounds us. Even after the sun has set, so that it no longer shines upon us, it is still shining upon the air above us, and it is this air, all flooded with sunlight, which makes it light. The evening light which comes to us from the air is called Twilight: if there was no air there would be no twilight; it would be bright daylight until the instant the sun had set and then it would at once become dark.

Astronomers have many times seen that there is a twilight on Venus. By watching the little line between the dark part of the planet and the part on which the sun is shining they have seen that the part of the world which is near the little line but which is not in sunlight is faintly lighted up. If there was no atmosphere around Venus this could not happen, for every part of the planet that was not in the sunlight would then look perfectly black. The little line is the border-land on this world between day and night; it is along this little strip that night is falling. And when we see a faint light shining on the little strip even after the sun no longer shines on it, we know that we are watching the twilight on our sister world.

WHAT WE SEE ON VENUS WITH A TELESCOPE.

Suppose that there is an astronomer on some one of the other great worlds that are moving around our sun, and that, armed with a large telescope, he tries to see what our own little earth is like. He points his telescope at a certain very bright little star in the sky which from his world he has seen moving around and around the sun every 365 days, and which is the planet that we call the Earth. As soon as he looks through his telescope he sees a beautiful sight. He sees that the bright earth is a round world, with large brownish patches on it which are the lands of our world, and that all around these and almost covering the rest of the ball there is something of a greenish color which we know is the water of the great oceans. And around the poles of the earth it would look brilliantly white to him, because these regions are always covered with ice and snow. He might not be able to look at a geography to see what the shapes of the great continents and oceans are, but the whole world would be there with everything in its proper place, and it would be turning slowly around, so that by watching long enough he could see every part of it.

With what interest he would watch this far distant world, and how he would study it to find out whether there were any living beings on it! But often while he was eagerly watching one little part of our earth it would be hidden from his sight. Great masses of clouds would drift over it and he could not see it again until they had passed away. Sometimes almost the whole United States would be hidden from him by the clouds in our air, and until our weather became clear he could see nothing of our land at all. It would all be buried under the bright, silvery-white mass of clouds which float in the air above it.

When we look at Venus we see a world which is altogether covered with just such masses of clouds. And no matter how long we watch we never see the skies grow clear in this cloudy world. Everything is always hidden from us, buried under the silvery-white clouds which entirely cover the planet; it is not certain that any one has ever caught a glimpse of what is underneath them. If all these clouds could be brushed away, who can tell what we would see? Some think that the world below is very hot and very damp; a world much warmer than a green-house, and on which warm rain is falling almost all the time. And they think that in this warm, wet land great trees and marsh plants are growing, and that great animals, like those which lived on our own earth many ages ago when it was very warm and damp, would be seen swimming in the marshes and wandering underneath the big trees of the forests. It is not impossible nor even very unlikely that this is true, but we do not know.

Sometimes astronomers have seen a few darkish markings on Venus and have thought that they may have been seas or continents seen dimly through the clouds. Sometimes bright spots have been seen near the poles which may have been ice or snow, and sometimes bright spots have appeared in other places which may have been snow on the tops of some very high mountains. But perhaps all of these things were only clouds a little darker or brighter than the other cloud masses around them. On the dark side of Venus, where it is night, there are sometimes faint lights shining which may be of the same nature as the beautiful Northern Lights that we sometimes see on our earth.

So that altogether, except for its interesting changes of shape, we can see very little on our nearest neighbor. If only the clouds could be brushed away, even for a little while! That is all that the astronomers would ask. But there they always are, shutting out what we want so very much to see. Perhaps someday someone will find a way to look through them to what is below, but we cannot think now of any possible way in which this can be done.

WHEN VENUS PASSES ACROSS THE FACE OF THE SUN.

We have seen how the little world called Mercury sometimes passes between us and the sun, and how it then looks like a round, very black little dot moving across the sun's face. Once in a very great while astronomers see our much larger sister world pass exactly between our earth and the bright sun too, but this is a far less common sight. It is so rare that it has only been seen five times since telescopes have been invented.

A transit of Venus is a most interesting sight. As the time draws near when the world is to begin to move in front of the sun, the astronomer points his telescope at the exact part of the sun's edge where he knows the planet will first be seen. Suddenly, as he watches, a little round notch begins to be cut out of the bright sun and he knows that this notch is the dark, round edge of Venus which is just beginning to overlap the sun's edge. And all around the dark ball of the planet he sees a bright little ring of light which he knows is the atmosphere of our sister world shining in the bright sunlight. As the hours go on, the little round, black dot with the ring of atmosphere around it moves steadily along, until it finally passes off the edge of the sun and the transit is over.

Whenever there is to be a transit of Venus, great preparations are made to observe it. In the year 1874 two parties of men came from Germany to the United States to measure the exact position of the little black spot as it moved over the sun, one party setting up their telescopes in Connecticut and the other in Texas. And more than fifty other parties in different parts of the world were taking photographs of our sun and Venus during the few hours that the transit lasted.

Why did they take so much trouble and come so far just to look at this little black dot as it moved across the sun? It is true that if one thinks how the little dot is a great world moving slowly along in its path, the sight is very interesting, and it is very interesting too to see the yellow little ring of light and to think that it is a deep atmosphere, but for this alone the astronomers did not build new telescopes and take so very many photographs. All their work was done to find out a very different and very important thing. For by measuring the photographs which were made in different parts of the world they knew that they would be able to find out just how many miles away our sun is from our earth. The photographs which were taken in one part of the world would show that the little dot seemed to move across the sun along a path which was a very little different from its path photographed from another part of the world. By carefully measuring all of the paths the distance to the sun can be found. There are many other ways of finding how large this distance is, and they all tell us that our great sun is almost ninety-three million miles away.

Venus will not again pass across the bright sun until the year 2004. Probably no one of us will be alive then, but we know that on June 8th of that year, at four o'clock in the morning, those who are then living on our world will see the little dot appear on the sun, and for six hours and two minutes they will see it move slowly across its bright surface.

CHAPTER VIII.

Our Earth as a Planet.

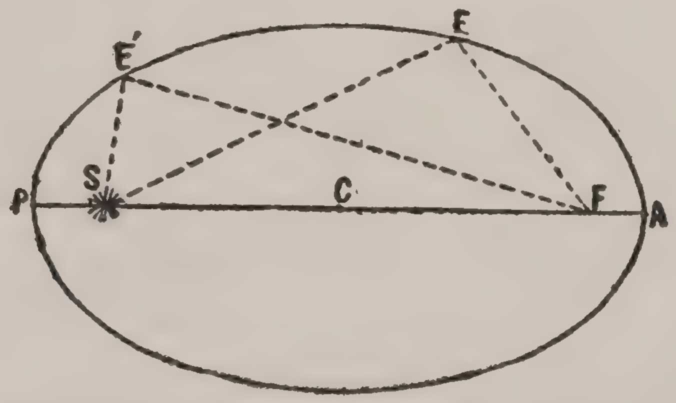
HOW OUR WORLD MOVES AROUND THE SUN.

IN telling about the planets, one after another, we now come to our own earth, which moves around and around the sun, just as all of the other planets do. Let us see if we can understand how it is that the great hot sun can keep all of these worlds forever moving around it.

If you tie a stone to the end of a string in your hand and swing it about your head you can get some idea of how the earth and all the other planets move around the sun. The path of the stone will be a circle and your hand will be at the center of the circle. You can feel the stone always pulling on the string and if you suddenly let go of the string, the stone will fly off in a straight line, and carry the string with it. You see that it is the pull on the string which keeps the stone traveling in a circle round and round your hand. If you whirl the stone faster, the pull on the string will be stronger, and if the string is weak it may break.

It is in just the same way that the earth is kept moving around the sun. There is no string connecting them, but there is a mysterious force, called Gravitation, that is always pulling the earth toward the sun, and which keeps it going around the sun just as the stone goes around your hand. This gravitation is so powerful that even though the great earth is traveling eighteen and one-half miles a second and is ninety-three million miles from the sun, yet it keeps pulling on our world so hard that it keeps it always moving in a circle.

The path which the earth moves in is, however, not an exact circle, as astronomers can show by observation. If it were a circle the sun would always seem to be of exactly the same size. But instead, the sun sometimes seems to grow a little smaller and sometimes a little larger, just as we see the headlight of a locomotive grow larger and larger as the train rushes out of the darkness down the track toward us. When the sun is nearest to us it looks the largest and when farthest away it looks smallest. Yet the change in its size is always very small. It is only when astronomers measure the distance across it very carefully that they find any difference. But by doing this they find that it always looks to be largest in our winter and smallest in our summer. This shows that the earth can not always be at the same distance away from the sun, but that it must be nearest the sun in winter and farthest away in summer.



The Curve called an Ellipse. The two tacks are at *S* and *F*, and the string is *SE'F* or *SEF*. The Sun is at *S*, but the center of the curve is at *C*.

The real path in which the earth moves is a curve called an ellipse. You can draw this beautiful curve in the following way. Take a sheet of paper; lay it on a drawing board, or on a flat table, and drive two tacks through the paper into the board. Then tie two ends of a string together, and pass the loop thus formed over the tacks. Move a pencil inside the loop, keeping the string stretched tight, and you will draw an ellipse around the tacks. If you change the distance between the tacks or change the size of the loop, you will get differently shaped ellipses. If you place the tacks quite close together the ellipse will look almost like a circle. It is in just such a curve that the earth and all the other worlds are moving. The sun is in the position of one of the tacks, and the earth moves just as the pencil point did. So that we see that the sun is not in the center of the earth's path, and why it is that the earth is so much nearer the sun at some times than at others.

OUR LITTLE COMPANION.

We have seen how the sun, by its enormously strong pull, can keep the earth and all the other seven bodies moving around and around it. And the paths of all these bodies are not circles, but they are all ellipses of different sizes. When we look at these worlds with a telescope we see that many of them have very small companions moving about them just as they themselves move about the sun. Each of these little companions, or moons, is kept moving in its path by the wonderful power of gravitation; that is, by the pull of its own world upon it.

If you could stand far out in space, far enough away to watch the earth moving around the sun, you would see that there is a small companion moving around and around our earth in just this way. This little companion is our moon. Sometimes you would see it move in front of the earth, and sometimes behind the earth, but it would never get very far from it. All the moons are moving around the worlds in ellipses and the worlds are not at the centers of these paths. When our own moon is nearest to us it is thirty-one thousand three hundred miles nearer the earth than when it is farthest away.

WHY WE HAVE DAY AND NIGHT.

The earth is a dark body, just as Mercury and Venus are; it can not shine in the dark as the beautiful stars and the sun do, which are such bright, hot bodies, that they shine brightly by their own light. Like all dark bodies, our earth will cast a shadow when light falls on it. As the earth moves around the sun, one side of it is always bathed in bright sunlight, while on the other side there is a long, round shadow which always stretches out into space exactly away from the sun. The people on one-half of the earth are looking into the shadow while those on the other half face the bright sunlight. If the earth did not turn around, on one-half of it there would always be day and on the other half there would always be night. We would have to make a long and expensive journey by land and water to get from the bright side into the shadow, or from the shadow into the sunlight.

But the big earth is always turning around, just like an enormous, spinning top. We can sit quietly at home, by the window, while it carries us around, more quietly and ever so much faster than the fastest express train; with no smoke, no dust, no cinders—until the light gradually fades away and we reach the blackness of the shadow. We do not need a return ticket, because the train only runs one way and besides it does not stop. You cannot get off. You are carried on through the shadow until at last you are brought into the dawning light and soon afterward come into the full sunshine again. So long as the earth turns around and the sun keeps shining we shall keep always traveling into the shadow and out again. And so night will always follow day, and day will follow night.

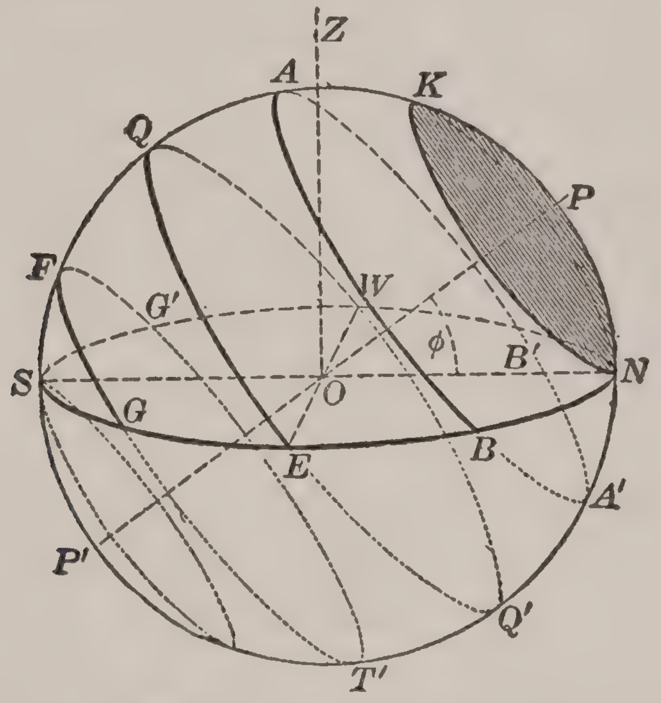
This is really what happens, but for very many centuries men did not know that the great earth was always turning. In the dawn they saw the stars slowly fade away and the sun mount up from the ground in the east, and move steadily across the sky, until it at last sank below the ground in the west. And so they thought that the great sun really moved around our little earth every day. Some thought that our world was a flat land surrounded by water and that when the sun reached the ocean in the west it was taken in a boat and carried to the east just in time to rise the next morning. And early people had many other strange ways of explaining why the sun seems to move over the sky as it does. But none of them knew how wonderfully large our sun really is.

Our earth turns so very smoothly and quietly that it is hard for us to understand how we are really always moving. But when we see the sun or other heavenly bodies seem to sink behind far distant lands or hills to the west of us, we should try to think how these bodies are not really moving down, but our slowly turning earth is lifting the land or hills up in front of them and so hiding them from our sight.

WHY THE STARS SEEM TO RISE AND SET.

Every one has seen how the sun and moon rise in the east, move slowly across the sky and at last set in the west. But there are a great many people who never notice how nearly all of the stars seem to be rising and setting too. And yet the stars in some parts of the sky seem to move quite rapidly. If you will turn toward the south and stand in such a way that you may see any bright star at just the left hand edge of a distant telegraph pole or chimney, then by holding quite still for only one or two minutes you will see the star move behind the pole or chimney and shine out again on the right hand side of it. This is a most interesting observation, and if you will make it on any clear, dark night, you will never forget afterward how rapidly the heavens are always turning.

If you spend several hours studying how the stars seem to be moving you will see that each one moves along in a curved path which does not come straight up from the ground, but leans over toward the south. Each path is like a great arch on the sky, and each arch is a part of a circle; we can not see the rest of the circles because they are below the ground. The nearer the star is to the North Star, the more of its round path we can see; if we watch stars which are near the North Star we will find that such stars seem to go around and around the North Star in little circles which are altogether above the ground, and so these stars never get below the ground at all; that is, they never rise or set.



The Sphere of the Sky. One standing at *O* will only see the *half* of the Sky which is above the circle *NESW*. The whole Sky will seem to be turning about the line *POP'*; the Stars will seem to be moving along the paths *EQW*, *BAB'*, etc. Stars so near the North Pole that they are inside the dark area *KPN* will never set.

We have learned that all of these stars are great suns, many of them millions of times larger than our little earth, and so it is not hard for us to feel sure that they do not really move around us as they seem to do. It is because the earth is always turning that the whole sky seems to turn around like a great ball. In just the same way, if one is standing on a large steamboat or ferry which is slowly turning around in the water, he seems to see all the water and the distant shores moving around him, although he knows they are not moving at all. The earth is turning from west to east, and it is this which makes the stars seem to move from east to west. The land we see in the west is really being lifted up in front of the stars and hiding them one after another, exactly as it hides the sun at the time of sunset.

WHY THE SUN SEEMS TO MOVE AROUND THE SKY.

Now that we know how the earth moves around the sun, it is not hard for us to understand why the sun seems to move around the sky. All around the earth and the sun, but at a very great distance away, there are the thousands and millions of stars. Sometimes our world is at a point of its path which is between the sun and a certain star group; then the sun seems to us to be on exactly the opposite side of the sky from these stars and we see them all night long. But six months later, when the earth has moved half way around its great path, the sun will seem to us to be in exactly the same part of the sky as these stars are. They will then only be above the ground when the sun is,—that is in the daytime,—and we can not see them at all.

And so, although it is really our earth which is moving, yet when we look at the sun from our moving earth it seems to us as if the sun itself is really moving slowly across the far distant background of the stars. In just one year the earth passes entirely around its path, and so at the end of a year it seems to us that the sun has moved entirely around the sky and come to be in just the same direction as when we saw it at first.

The path which the sun seems to follow over the heavens is called the Ecliptic. A little strip of the heavens stretching all the way around the sky along the ecliptic is called the Zodiac, or Zone of Animals. There are twelve star groups in this zone and they were nearly all named after animals very many years ago. Many of these star groups were known long before our earliest history begins, but some of them were probably given their present names by the early Egyptians or Babylonians. Thus, Leo, or the Lion, is the group into which the sun moves in mid-summer, and it was perhaps so named either because at this time the sun is most raging and hot like a lion, or because when the sun was here the lions left the desert to escape the great heat and were seen on the banks of the Nile.

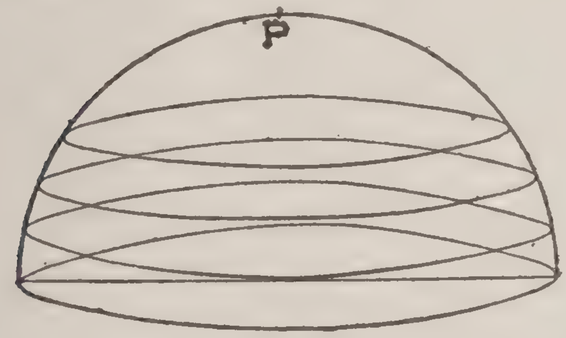
If we could draw the path of the sun among the stars, we would find that it was a great circle passing all the way around the sky, but this circle would not lie half way between the north and south poles as the equator of the earth does. We would find that it lies in an inclined direction, so that one-half of it is in the north hemisphere of the sky and the other half in the south hemisphere. The sun, passing along in its path, enters the north hemisphere about March 21; it moves farther and farther north until about June 21, and then turns and moves southward again. For six months it is in the north half of the sky and for the other six months of the year it is in the south half. When it is farthest north we have our longest day and shortest night, and when it is farthest south our day is the shortest of the year and our night the longest.

THE LAND OF THE MIDNIGHT SUN.

We have seen how the whole sky looks to us as if it were the inside of a great hollow ball, and how it seems to be always slowly turning. If every star as it moved from east to west could leave a little bright trail behind it to mark its path, we would see an immense number of circles drawn around the sky, and each circle would be the path along which a star seems to move.

The center of every one of the circles would be very near the North Star. And so some of the circles would be quite small, and these would be the paths of the stars which are near the North Star on the sky. As we looked at stars farther and farther away from this part of the heavens their circles would be larger and larger, until soon we would come to circles so large that they could not be wholly above the ground; the stars moving along these circles would, therefore, pass below the ground sometimes,—that is they would rise and set.

It is very easy by using a common photographic camera to show in a very beautiful way how the stars all seem to be moving around the North Pole of the heavens. On some clear night, when the bright moon is not shining, we set our camera firmly up out of doors and point it straight at the North Star. We leave it there all night long and when we then examine the picture we find it all covered with perfect little circles. Each circle has been made by a moving star; near the center there is a very small circle made by the North Star itself, which shows us that this star is not exactly at the north pole of the sky.



The Sky as seen at the North Pole of the Earth. The Pole Star is there directly overhead at *P*, and the paths of the Stars are everywhere at the same height in the Sky.

Suppose that we walk over our round earth, moving always toward the north. Above us there is always the great, round sky, but because our world is round too the part of the sky which is exactly over our heads will keep changing as we walk. When at last we get to the North Pole of the earth we will see the North Star exactly above us. And then the centers of all the circles in which the stars seem to move will be exactly overhead. If we could see the circles all drawn around the sky, there would be little ones above us, and outside of these there would be larger and larger ones, until at last we would see the largest one of all lying right along the surface of the sea, where the sky and water seem to meet. And none of the stars would rise or set. They would all seem to move along the circles, never getting any higher up or lower down in the sky.

So that if we were at the North Pole of the earth we would see one-half of the sky; the North Pole of the sky would be exactly above us, and so it would be the north half of the sky which we would see. We have learned how the sun seems to move all the way around the sky in one year. For six months of the year it is in the north half of the sky and during the next six months it is in the south half. So all day and all night long, week after week, for six whole months, men who are at the North Pole of the earth see the sun shining, and then it passes into the south half of the sky and for the next six months they have one long night.

Let us think of ourselves in the far north in early March, when the sun in its journey among the stars is daily drawing nearer to the north half of the sky. For many days we have seen a beautiful glow stretching upward from the distant ground or ocean, and ever steadily moving all the way around us as the hours go on. Each day the faint dawn grows brighter; the stars which have been shining out above us for nearly six months disappear in the brightening sky, and at last the edge of the bright, round sun appears above the ground, and the long day has begun.

Day after day, the sun moves very slowly upward, but it does not rise or set; it coasts along the distant edge of the ground or ocean, never getting much higher up or lower down. Three months after it first appeared it begins slowly to sink downward again, and a little more than three months later it disappears from the northern sky. Then for many days there is the ever-moving twilight glow, but this grows fainter and fainter and at last disappears entirely. Then for the unfortunate dwellers in these cold regions there begins the long northern night, whose darkness is only relieved by the regular appearance of the moon and the shining of the beautiful Aurora Borealis.

WHY IT IS WARM IN SUMMER AND COLD IN WINTER.

The earth as it turns spins continually about a line which passes through its center, exactly as a spinning top does. The line about which the earth is always turning is a straight line joining the north and south poles; this line is called the Axis of the earth.

The earth's axis always lies in the same direction, even when the earth is moving around the sun. It does not extend exactly upright from the path of the earth, but leans over, so that sometimes the north end of the axis is leaning in the direction of the sun and sometimes away from it. If you think of a knitting needle pushed through the middle of a round ball, this will stand for the earth's axis, the upper end of the knitting needle being the north pole and the other end the south pole.

If you next carry the ball around a lamp, holding the needle so that it does not point straight up from the floor, but leaning it a little, and being very careful not to change the direction in which it points as you move around the lamp, you will have a very clear little image or model of the earth as it moves around the sun. You will see that part of the time the upper end of the needle points toward the lamp and the lower end away from it, and that when you get to the other side of the lamp, if you have not changed the direction of the needle, it will be the lower end of the needle which points toward the lamp and the upper end which leans away from it.

It is just the same way with the moving earth. Its axis does not change its direction, but in one part of the earth's path its north end is leaning toward the sun and in the opposite part of the path the north end is leaning away. As long as the north end leans toward the sun the sun is shining on the north pole of the earth and we who live in the north half of the world see the sun much more nearly overhead than when the north end of the axis is turned away from the sun. It is then that we have summer, but at this same time the south pole of the earth is turned away from the sun, the south polar regions are in darkness, and the people who live in the south half of the world are having winter.

When it is summer in North America, it is therefore winter in South America. The hottest time of our year is generally the beginning of August, but in southern lands this is the coldest time of the year. There the hottest month is usually February, but this is the coldest month with us. If in September you should journey to South Africa or to Patagonia, you would find that their winter snow was just melting away and all the grass and trees beginning to grow. For September to them is exactly the same as March is to us: it is the month which marks the end of winter and the beginning of spring.

When the north end of the earth's axis begins to lean more and more toward the sun, we see the sun each day mount higher in the sky and shine more directly down on us. For this reason alone the days would then keep getting warmer. But we have seen that the nearer a body in the sky is to the North Star, the longer it will remain above the ground, and that the stars quite near the North Star never set at all. And so as the sun climbs higher in the sky it rises earlier and sets later each day, and then the days get longer and the nights shorter. As the sun is shining on us for a longer time each day, this helps to make the weather grow warmer too.

By about June 21 the sun has reached its highest position in the sky. It then rises far in the northeast and sets far in the northwest, and the day in the northern United States is almost six hours longer than the night. Then it begins to move downward.

The days shorten and the nights lengthen, until on about September 22 they are of equal length. From this time on until about December 21 the days keep growing shorter and the nights longer, but after this date the sun again begins to move upward in the sky and the days again begin to lengthen.

The times when the days and nights are equal are called the Equinoxes. The spring equinox comes about March 21, and the autumn one about September 22. When we in the north part of the world are having the longest days, the people in the south part are having their shortest ones, and at the time when our days are shortest theirs are the longest.

CHAPTER IX.

The Moon, the Lamp of Night.

OUR LITTLE COMPANION.

THERE are a great many people in the world who know almost nothing about the beautiful things in the heavens. Night after night the brilliant host of stars, the wonderful star clouds and clusters, and the nebulas shine out above them, and yet they never notice them at all. They do not even know a single one of the bright stars by name; they do not know that some of them are reddish and some yellow and some blue. They do not know how some are very hot and some cooler, how some are new and some older, and how they are all great suns so very far away. How much pleasure such people miss by never thinking about the multitude of interesting things which fill the sky!

But there is one heavenly body which everyone knows by name, and yet it is the very smallest of all the bodies they have ever seen in the sky, unless they have at some time looked through a telescope. This is our moon, a little round world which moves around and around our earth and which seems so large and bright to us only because it is so very near us. In telling the story of the worlds which move around our great sun we begin with the sun itself and journey outward farther and farther from world to world. It is not until we reach our earth that we find for the first time a world which has a little world moving around it. But from now on every world we visit will be attended by little worlds or moons; we will even find that one great planet has as many as ten moons moving around it, some of them much larger than our own moon is.

Our moon is a solid, cold little world. The distance through it is almost exactly one-quarter as much as the distance through our earth. We will see that there are no seas, or oceans, or water of any kind on it; it is all land, and there is almost exactly as much land on its surface as there is in North and South America together. If we take a base-ball three inches through and a round foot-ball eleven inches through, and if we put the two balls out on a level lawn or on the floor of a very large room so that they are thirty feet apart, we will have a perfect little image or model of our earth with the moon near it.

The large ball in our little model is our earth, and the small one is the moon; by looking at them we can see just how much larger than the moon our earth is. But our earth is much heavier than the moon. It is almost as heavy as if it were a great piece of iron, while the moon is only about as heavy as a stone of the same size. If we could put the earth in one of the pans of a pair of scales, we would have to pile up eighty-one moons in the other pan before the weight of the moons balanced the weight of the earth.

WATCHING THE MOON IN THE SKY.

When we see our beautiful moon shining in the sky with its soft, steady light we must think of how it is really a great round world that we are looking at. And it is because this moon-world is always moving around our earth that it keeps changing its place in the sky from night to night. If tonight we see it shining out from among the stars which form the great constellation of Taurus, or the Bull, then tomorrow night we will see that it has moved far to the east of this group of stars and is among those which form the group called the Twins. And it keeps moving farther and farther eastward until in a little less than a month it has moved all the way around the sky. In one hour it moves a distance equal to its own width;

that is, at the end of one hour its western edge has moved ahead to where its eastern edge was at the beginning of the hour.

There is no one who has not noticed how the shape of our moon seems to be always changing. Perhaps we first see it some evening shining out low down in the west just after sunset. It looks like the narrowest, pale, little crescent, floating in the twilight glow, so low down that it sinks beneath the ground before night comes. The next night we see it so much higher up in the sky that it sets nearly an hour later, and the little sickle-shaped crescent is much wider than it was before. And so it keeps moving farther eastward and growing larger and setting later until at last it is a round, full moon and does not set until about six o'clock in the morning. At this time it shines on our earth all night long.

After the moon has become full it begins to slowly change to a crescent shape again, and as it keeps on moving steadily eastward it sets later each night and rises later too. At last it gets so near the part of the sky in which the sun is shining that it rises only a short time before sunrise; it can then be seen as a little narrow crescent shining out in the east for a little while before daylight comes. Soon after this it passes to the left of the sun in the sky; then the sun rises first and when evening comes the sun sets first and we again see the moon shining low in the western sky after sunset, just as we saw it a month before.

So the moon is always somewhere in the sky and always moving steadily eastward. Often we can see it in the daytime when it is not too nearly in the same part of the sky as the sun, but wherever we see it first, if we keep watching it we will soon understand just how it is moving and how its shape is always changing.

It was by watching the moon that the very first men began to learn about astronomy. They soon saw that the time from when the moon passed the sun until it got half round was just as long as the time from when it was half full to when it was full. And this time was called a Week. And the time from one full moon to the next, which is twenty-nine days and nearly thirteen hours, was called a "Moon," or a Month. Very many of the savage nations today count time by the moon. They do not remember long enough to talk about years, but they will say that they planted corn four moons ago, or that a long journey was two moons long. And many savages have dances and a joyful celebration each month to welcome the little crescent moon when they first see it in the western sky. To these poor people the moon is so very important that some of them even worship it. It brightens up their dark nights so much that when it is shining they can go about almost as if it were daytime.

WHERE THE MOON LOOKS UPSIDE DOWN.

When we look at the full moon we see grayish markings on it, looking something like the eyes and nose and mouth of a round face, and this is known to everyone as "The Man in the Moon." Some of the dark markings form the figures of a Lady, and of a Donkey, and of a man bending over with a bundle of sticks on his back, but these are not so clearly seen as the face. Men have always wondered what these dark markings are. Some even thought that the moon is like a mirror and that we see in it the countries and oceans of our earth. When Galileo first looked at them with his telescope he saw clearly, however, that there is here a wonderfully interesting little world covered with mountains and hills and plains and many other things.

If you should go to South America, or to Australia, and look at the full moon it would appear strange and unnatural to you. You would, in fact, see it exactly upside down, and the markings instead of looking like a face would look more like a ship with sails. So people in southern lands say there is a ship in the moon, instead of a man in the moon.

The moon would look this way to you because our world is not a flat plain as it seems to be, but is really a round world. The highest point of our sky is always directly over our heads. If we stand in North America this highest point will be on one side of the moon in the sky, but if we walk southward around the round earth our head will in time be just under the moon, and if we go still farther the highest point of our sky will come to be on the other side of the moon from where it was at first. So that at first we see one edge of the moon highest up in the sky, and afterward just the opposite edge seems highest up; that is, the moon seems to have turned just upside down.

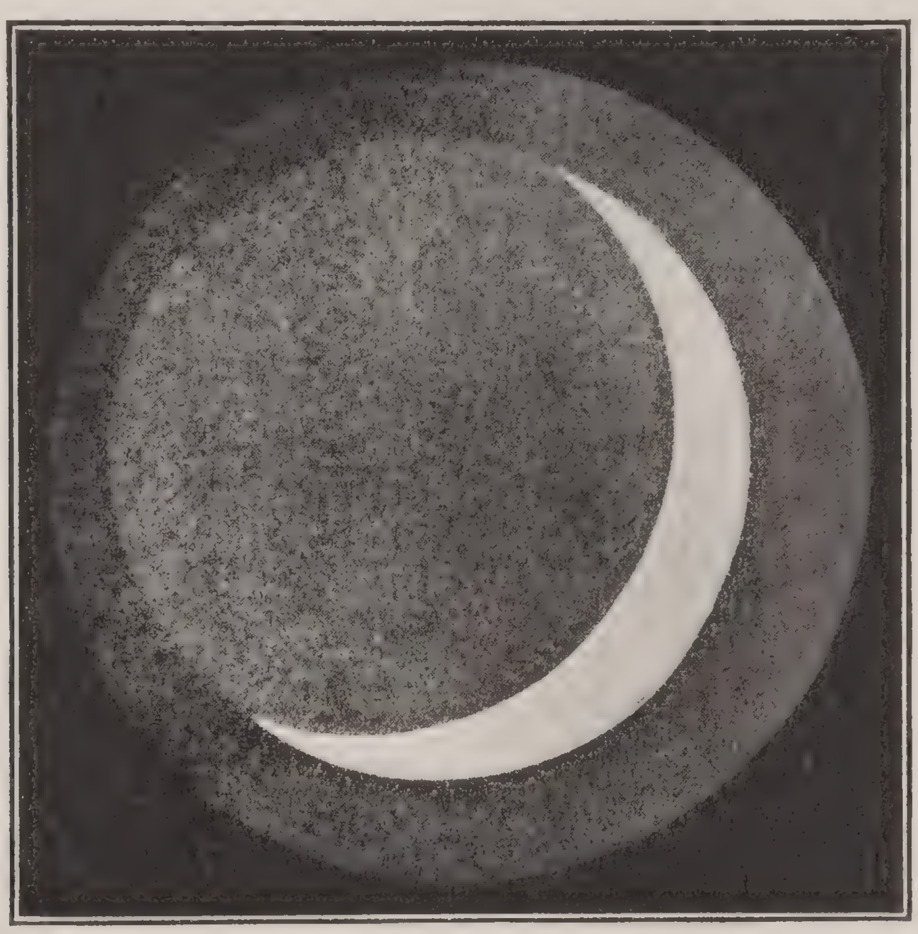
WHY THE MOON SEEMS TO CHANGE ITS SHAPE.

The moon is a dark world just as our own world is; it does not shine at all by itself, but it only looks bright to us because the sun is shining on it. We see it shining just as we sometimes see the clouds shining brightly when they are in the sunlight, and we cannot see any part of the moon unless that part is in sunshine. As the moon is round, there is always just one-half of it which is in sunshine and one-half of it in darkness, just as on our own earth one-half is always lighted up by the sun while the other half is dark.

Sometimes it is exactly the half of the moon on which the sun is shining that is turned toward us and then we see all of this world on which there is day. It then looks to us like a round, full moon because all of the world on which we are looking is in sunlight. When the moon is between us and the sun the half toward the sun is lighted up, but this half is turned exactly away from us; the half on which we are then looking is in darkness so that we cannot see the moon at all. When the moon is almost, but not quite, between us and the sun, the sun-lit side is not quite all turned away from us; nearly all of the moon turned toward us is then in darkness, but we see a little strip of the bright part, so that the moon looks to us then like a narrow little crescent. And usually the side of the moon turned toward us is partly in sunshine and partly in darkness, and as we can only see the regions where the sun is shining, a part of the round moon at which we are looking will be dark and the rest bright; we will then not see the whole round moon but only the sun-lit part of it.

"THE OLD MOON IN THE NEW MOON'S ARMS."

Even when the moon looks to us like a very narrow little crescent we should think of how the whole round moon is there in the sky but that we cannot see all of it because most of its bright side is turned away from us. But at this time we sometimes see a most interesting and beautiful sight. As the narrow crescent hangs low in the western sky, we see a dully shining, ashy colored, round ball which seems



"The Old Moon in the New Moon's Arms."

to lie in the hollow crescent and to fill out the circle of the round moon. It is in fact the night side of the moon which we are seeing; it is dimly lighted up, but it is not nearly so bright as the crescent which is in full sunshine. This faintly shining ball is sometimes called "The old moon in the new moon's arms."

What is it that is shining on the dark side of the moon and making its night so bright? If we could go there we would see at once, for high in the sky we would see a great, round, brilliant world pouring down sixteen times as much light as we ever get from our moon. This beautiful world is our earth, which with the bright snow around its poles and the silvery clouds in its air would shine most brightly in the sunlight. We would see it change its shape from New Earth to Full Earth, and then back again to New Earth, just as the moon does.

If we stood on the night side of the moon when the moon is a narrow crescent it would be the day, or sunlit side of the great earth which would be turned toward us. To us who come from the earth the night would seem wonderfully bright. The nearly full earth in the sky would pour down as much light as sixteen full moons. Yet all this light is only one forty-thousandth part as much as the sun gives in the daytime. It is no wonder that the little round black ball which we see inside of the crescent is so much fainter than the crescent itself. In Germany they call this faint light the "Earthshine."

A ROUGH AND RUGGED WORLD.

As soon as we look at the moon with a telescope, what a wealth of interesting things we see! There are great mountains and mountain peaks three and four miles high, and some even higher: there are great plains hundreds of miles across, surrounded by rough hills, and both these hills and the great mountain peaks are very much more steep and rugged than the mountains on our earth are. In some places there are rifts on the floors of the plains which look like rifts of sand blown by winds in the desert; in others there are black cracks half a mile wide and hundreds of miles long, and no man knows how deep they are.

All over the moon there are thousands upon thousands of craters showing where once great volcanoes were. The eruption of a volcano on the earth, as it pours out fire and steam and melted rock, is a grand and terrible thing to see, but no volcano which was ever on our world can compare with the terrible volcanoes which were once erupting on the moon. Many of the moon volcanoes are sixty miles across, some are even as large as one hundred miles, while those from five to ten miles across are numbered by hundreds. The distance across the largest crater of any volcano on the earth is only eight miles.

All of these things are seen most clearly when they are near the edge of the bright part of the moon. It is this edge which is the boundary between the half of the world which has day and the half which has night; if one were standing there he would see the sun either just rising or just setting. As the sun is so low down in the sky when viewed from this part of the moon, every crater and peak and little hill here casts a long, deep, black shadow. This makes them stand out so very clearly in the telescope that we can see just what their shapes are.

Sometimes when we are watching the rough edge which separates day from night on the moon, we see many little points of light flash out on the dark, night side of the moon. These are mountain peaks on which the sun is shining, and they look like little points of light separated from the rest of the bright moon, because while both they and the day side of the moon are in sunshine, the valley between is in darkness. By watching a little while we see the sunshine slowly move down the mountain sides until on the mountains and the valleys and all the land around there is day.

The Moon when about half full as seen in a small telescope.

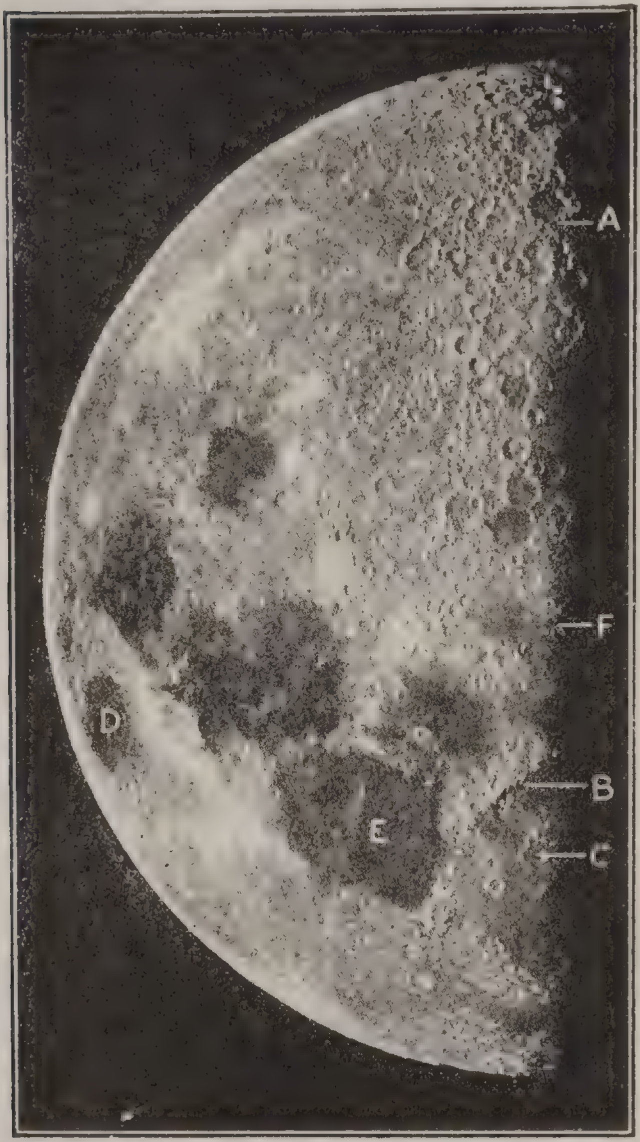
THREE VIEWS OF LUNAR SCENERY.

Let us take a very large telescope and study more carefully some of the parts of this strange little world. There is so much that is interesting that we hardly know where to begin, but a little below the center of the moon we see a long, striking, very rough mountain range, so let us point our great telescope at that.

What a wonderfully rough country it is! We see great masses and hills piled on top of each other to greater and greater heights until the top of the great mountain range itself is reached, which towers four miles above the almost level plain at its foot. Such wonderfully rough, steep places, piled so strangely upon one another, are like nothing we have ever seen on the earth.

If we could stand on the jagged mountain summit what a scene of desolation would meet our view! Behind us would be the hundreds of miles of hills and volcanoes jumbled together in a most extraordinary way. Before us we would look down the steepest precipice, four miles high, to the almost level plain which lies far below us. The plain is covered with mounds and craters whose great shadows look deeply black in the sunlight, and on its floor are deep cracks or chasms which probably go down many miles into the body of our new world. Over all of this wild and wonderful scene an absolute stillness reigns. There is not a sound, not a breath of air, not a motion. We see no rivers or lakes, no animals of any kind; no plants or any living thing at all. It is a dead land which we are looking at; a land of absolute desolation.

But how different it must have been in the ages which are past! What terrible forces they were which once piled up these great mountain masses! Far away over the plain there is a crater fifty miles wide; the hardened lava around its edge is heaped up two miles high. All the country near it is broken by chasms and covered with smaller craters which tell a wonderful story of how this land must once have been torn by terrible volcanic forces.



The Half Moon as viewed in a small telescope. The large grayish areas at *D* and *E* are called the Sea of Conflicts and the Sea of Serenity, respectively. At *B* is the range of Mountains called the Apennines, and the great Crater near these at *C* is named Archimedes. Tycho is just to the right of *A*, and Copernicus far to the right of *F*. Both of these Craters are still on the night side of the moon so that we can not see them in this picture; they may be seen however in the picture on page 120.

The mountain range is named the Apennines; the great crater is called Archimedes, and the plain is called the Imbrian Sea. Near Archimedes there are two other great craters; one of these, which is very deep, is thirty-four miles wide and has a cone or mound of lava in the center. An immense amount of melted material must have been poured out of this crater, for we see it stretching away across the plain in great ridges forty and even fifty miles in length.

Let us look next at a great crater which we see almost in the middle of the moon, beyond the Apennines. This is more than fifty miles across, and in its center there is a mountain half a mile which is topped by six pointed mountain peaks. All around the inside of the crater wall there are steps or terraces made by the great central sea of molten lava as it rose and sank.

It is an especially beautiful sight to watch this great crater when it is near the border line which divides day from night on the moon, and when the sun is just beginning to rise on it. First the top of the round crater wall is bathed in sunshine; then the peaks of the central mountain flash out as bright points, one by one. Gradually we see the sunlight moving down the mountain sides until all of the mountain and the crater wall are in light. At last the level floor which has been in black shadow, is lighted too, and throughout the whole great crater it is day.

For our last view, let us point our telescope near the upper edge of the moon where there is the largest crater of all. This is the great Tycho, a crater three miles deep which has a peak or cone in its exact center more than a mile high. But what is most wonderful about this part of the moon is the extraordinary number of craters which we see here. There are hundreds of them, crowded so closely together that the whole country is nothing but a mass of over-lapping craters. A walk across it would be nothing but climbing up and climbing down one crater right after another, and the crater walls are so wonderfully rough and steep that even in many days we could only go a very little way.

WHAT WAS HAPPENING ON THE MOON BEFORE THERE WERE HUMAN BEINGS ON THE EARTH.

All over the moon we see the clearest signs that here was once the scene of a wonderfully violent energy. The little world continually trembled with moon-quakes; from the explosions of thousands of great volcanoes melted rock was blown high into the air, and explosion followed explosion so rapidly that the whole moon became covered with volcanoes, and the newer volcanoes crowded and pushed aside the older ones. But now all this is over. All the volcanoes are dead, and search the moon as we may, we never see any change or motion on it any more. Our moon is a still, dead world.

Why did this little world die so quickly, and why was it the scene of such wonderful and terrible energy when it was young? Our own world is growing old slowly; for many ages to come it will be the same warm and pleasant world that it is now, and we do not believe that it was ever torn by great volcanic explosions all over its surface as the moon was. What has been the past history of these two worlds and why are they so very unlike?

We believe that many, many ages ago the moon and the earth were two great, very hot, round balls; that they were made out of just the same things that we find on the earth now but that all these things were so very hot that they were melted and even in a state of vapor. We have seen that our sun is like this now, and we will find that some of the worlds which move around our sun are still so hot that there is nothing solid about them.

The earth, the moon, and all the other worlds have always been in the great ocean of ether which is very cold indeed; its temperature is not far from 460 degrees below zero. Ages ago the hot earth and the moon were in this great cold. But the moon is so very much smaller than the earth that it grew cold very much more quickly, just as if you put a little hot iron ball and a large one out in the cold the little ball will get cold very much sooner than the large one will. So the moon got cold and solid long ages before the earth did.

Now we know that as any body gets colder it shrinks together. There came a time when the outside of the moon was a solid crust and when all the inside was a great, hot, molten sea, and then the moon was always losing its heat, and the crust was getting thicker and shrinking together, and pressing harder and harder on the central part. And whenever the pressure on the melted center got strong enough, the crust was broken and the melted rocks and lava rushed out with terrible energy. But all the time the moon was growing colder. At last it became a world solid all the way to its center and after that there were no more explosions on its surface.

Probably all of this happened before our earth had begun to get solid. If the first man who lived on our world could have looked at the moon with a telescope he would probably have seen everything there just as we see it today. Its life was a short and active one. It lived its whole life through during only a part of the time in which our far larger earth was very slowly cooling and shrinking, and quietly becoming fitted to be the home of man.

WHY THE SURFACE OF THE MOON IS SO ROUGH.

If you could go to the moon you would feel strangely light; if you weigh one hundred pounds on the earth you would weigh only seventeen pounds there, and if you could jump five feet high here you could jump thirty feet high there—as high as the top of a house. This is because the moon is so very much smaller than the earth that it could not pull down on you nearly so hard as the earth does.

Everything on the moon weighs only one-sixth part as much as it would if it were on the earth. And this is one reason why the volcanoes on the moon were so very large. An explosion which would hurl rocks and lava five miles away on the earth would throw them to a distance of thirty miles on the moon. And we know that the explosions which occurred on the moon were more violent than those which have occurred on the earth.

But there is another reason why the mountains and hills of the moon are so jagged and rough. On our earth the winds and rain and frost are always wearing everything away. Little by little the rains wear away the tops and sides of the mountains, the water works its way into the cracks of the rocks and then freezes and breaks them to pieces, and both the earth and the rocks of the mountains are very slowly washed down into the valleys. So that nearly all of our mountains are much lower and more rounded than they used to be.

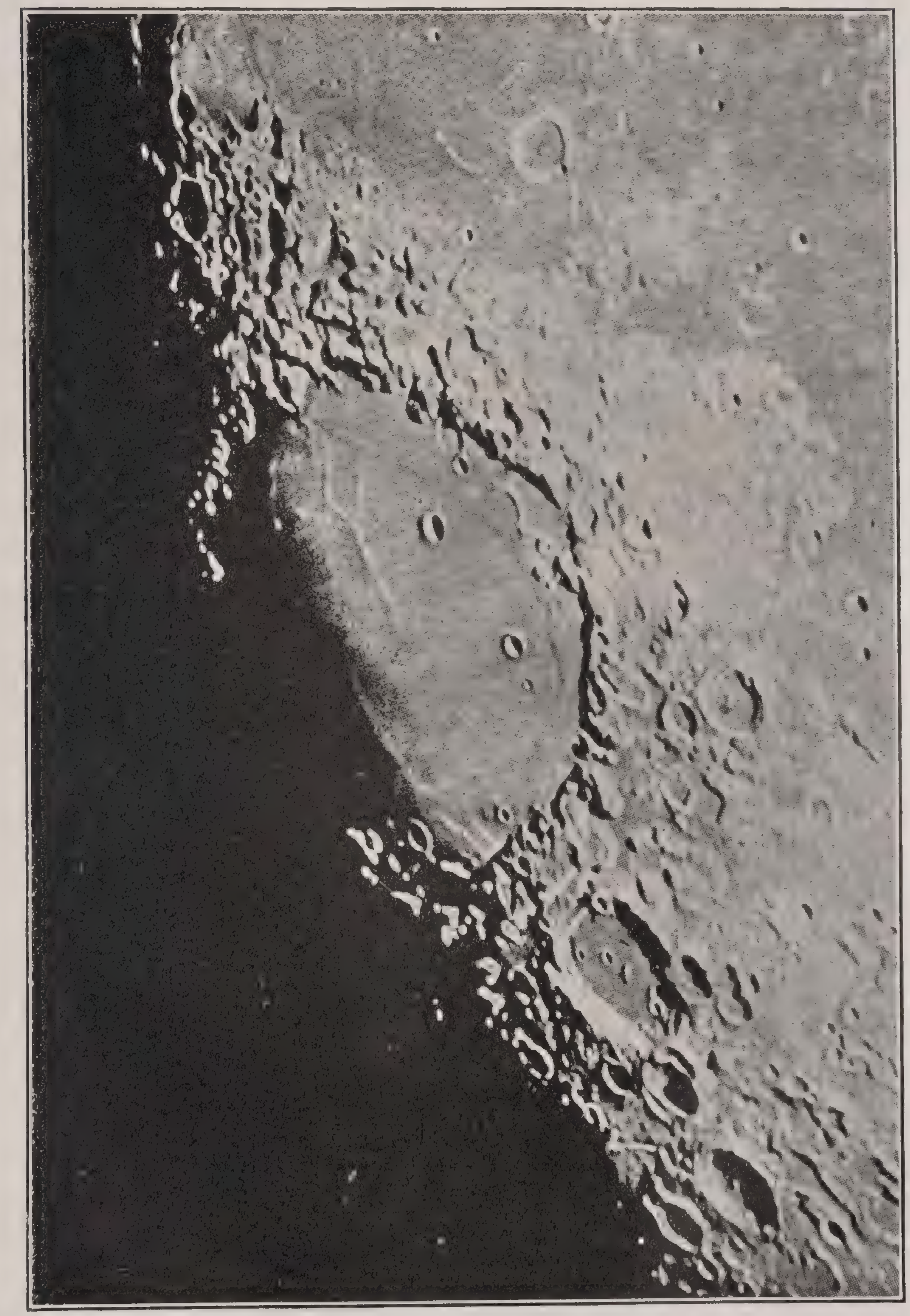
On the moon there is no air and no water. If a great pointed mountain peak is thrown up by an explosion no winds or rains begin to wear it away, as they would do if it were on the earth. There it will stand, age after age, with its pointed summit and its rough sides, always remaining just as they were at first.

A VISIT TO THE MOON.

Let us suppose that we have just landed on the night side of the moon, not far from the region where the sun is shining. In the east we will see hundreds of sharp mountain peaks, brightly lighted up by sunshine, and soon the slowly turning moon will bring us into the sunshine too, and it will be day.

While we wait let us look about us. It is intensely cold, far colder than it has ever been in even the coldest place on our earth. If we could measure how cold it is with a thermometer we would find it at least two hundred degrees below zero, and probably even colder. And there is no air around us: we cannot breathe, and everything is perfectly still. If we walk we hear no footsteps, and even if we shout we hear nothing. If we look upward we see the whole sky packed full of thousands and thousands of stars which we could not see when we looked through the air of our earth but which here shine brightly. And among these is our great round earth itself looking sixteen times larger than anything we ever saw in the sky before.

Suddenly as we wait the day comes. There is no slowly brightening dawn as we see on the earth, but in a flash the sun's light strikes us and the night is changed to day. Everything on which the sun shines



THE SEA OF CONFLICTS.—There are great rifts and craters on its floor and the sun is shining on the top of some of the hills which are to the left of it. At the time this photograph was taken the sun was setting on this part of the moon.

is brightly lighted, and we are struck by the rough and jagged nature of the strange country on which we are looking. All the hills and rocks throw deep, inky-black shadows; nothing is softened by air as it is on our earth; even the most distant craters stand out as sharply and clearly as if they were only a few feet away.

And everywhere there is the most absolute stillness and rest. If we are on one of the great plains we probably find it covered deep with volcanic dust, but each little grain of dust rests just where it fell ages ago. From time to time a swiftly flying meteor falls noiselessly from outer space and buries itself upon this dead world, but we see no other moving thing.

For a whole week the sun mounts higher and higher in the heavens, the land grows brighter and the shadows shorten. Then it begins to sink again; the shadows lengthen, and at last, two weeks after the break of the long day, darkness suddenly falls upon us, and the long lunar night has begun.

THE SIDE OF THE MOON THAT MEN HAVE NEVER SEEN.

All the time that the moon is moving around the earth it keeps the same side turned toward us. This side alone we can see, but no man has ever looked upon the other side of the moon, nor will any living being on our earth ever see it. If we could, what would we find there? Is it possible that that mysterious, hidden land is warm and pleasant, a very different kind of place from the cold, still part we know so well? Is it possible that there is any air or water there, that there may, after all, be living beings on this little world which is so near us?

Once men thought so, but now we know that these things cannot be. If there was any air on the other side of the moon we know that it would certainly spread around to our side too, and this it does not do.

And because there is no air there we know that it cannot possibly be warm. What great mountains and craters we would see if this world could be turned half way around we do not know, but we are quite sure that in this unseen land stillness and silence forever reign.

STRANGE IDEAS ABOUT THE MOON.

A good many people who do not know better think that the moon has a great deal to do with living things on the earth. Some gardeners set out trees and other plants at the time of the month when the moon is past full, for they say that then it will press the roots into the ground more firmly and in this way make them grow better. We once had a gardener who would not set out trees or even fence-posts while the moon was new, because he thought that as it grew more and more full it would pull on them harder, and at last actually pull them out.

Many people used to think that it is very harmful to stay for a long time in the moonlight. They thought that if one were so reckless as to sleep where the moon-shine fell on his face his mind would be entirely destroyed. The Latin word which means moon is Luna, and it is from this strange belief that our English word Lunatic has come to mean a person who has lost his reason.

There are other people who know better than to believe any of these things, but who think that the moon has much to do with the weather. When the moon is nearly new we see it as a little narrow crescent with its horns turned up from the ground. Some think that at this time it holds up the water and so our air is dry, but that later, when it loses its hollow shape, it spills the water out again and then we have heavy rains. Others believe just the opposite: they say that the full moon "eats up the clouds," so that we only have much rain when the moon is not full.

All of these foolish sayings, and many others like them which we sometimes hear, are altogether untrue. The moon does pull on the earth, for, as we will learn later, every body in the universe is pulling on every other body. When the moon is exactly over your head it is pulling up on you, and then you weigh a little less; but how hard is this pull? It is easy to find out very exactly. It is easy to prove that if you weigh one hundred pounds, the moon can only lift up on you with a force of one six-thousandth of an ounce. This is much too small a pull to have any effect whatever.

As to the moon holding up or emptying out water, now that we have learned how very far away from us it is, and how it really does not change its shape as it seems to do, we can see how impossible that is. And most unfortunate of all, is the fear of that soft, pleasant moonlight, which we know can not possibly hurt anybody. So, when you meet any person who knows so little about astronomy that he believes any of these things, perhaps you can explain to him how mistaken he is.

HOW THE WATERS OF THE SEA ARE ALWAYS RISING AND FALLING.

Everyone who has visited the seashore knows that twice each day there is a time of high water and twice each day a time of low water. As the time of high water draws near, the waves of the sea run continually farther and farther up on the shore until a great deal of the beach which was dry land a few hours before is buried deep in the ocean. For a little while we see no further change, but before long we notice that the water is very slowly getting shallower again. Six hours and thirteen minutes after the time of highest water the ocean has become lowest; then it again begins to rise, and so day after day throughout the years, high water and low water continually follow one after the other. The waters of the oceans are never quiet as those of a little lake are; they are always either rising or falling. This never-ending rise and fall of the waters of the sea is called the Tide.

If we were on a small island far out in the ocean, the water might rise only one or two feet at the time of highest tide. But on narrow bays along the shores of continents the change is very much greater than this. In the Bay of Fundy, in the Gallegos River in Patagonia, and in many other arms of the sea like these, so great a mountain of water rushes in from the ocean that at high tide the water of these bays is fifty feet deeper than at low tide. On the east shore of Hudson Bay there is a round harbor which is joined with the bay by a narrow strait between two towering mountains of rock. When the water of the bay is rising it pours through this narrow strait with terrible swiftness, and as it falls there is just as strong a current in the opposite direction. It is only for a little while, at about the time of highest or lowest tide, when the water is neither rising or falling, that any boats can pass through the narrow strait.

The tides do a great deal of good for man by scouring out the sand and mud from these bays twice each day and keeping them pure. Many of our largest cities are so far from the sea that no ships could come to them or leave them if the water did not rise and fall; it is only at high tide that the ships are lifted over the harbor bars and carried to the wharves. The great city of Liverpool is thus situated at the mouth of the Mersey River. Every six hours, six hundred million tons of water rush in or out of its harbor, scouring out its channel and making it possible for ships to sail into it. The Avon at the city of Bristol is but a shallow ditch at low tide: six hours later it is a broad and deep river on which the largest ships can sail.

The time of day at which high water comes is always changing. If on one day there was high tide at six o'clock in the morning, there would also be another high tide on the same day at twenty-six minutes past six in the evening. But on the next day both high tides would come just fifty and one-half minutes later; by the end of one week the first high tide would occur at seven minutes before noon, and the second at twenty minutes after midnight. Sailors and fishermen whose work depends on the state of the tide must therefore go to work at all different hours of the day and night.

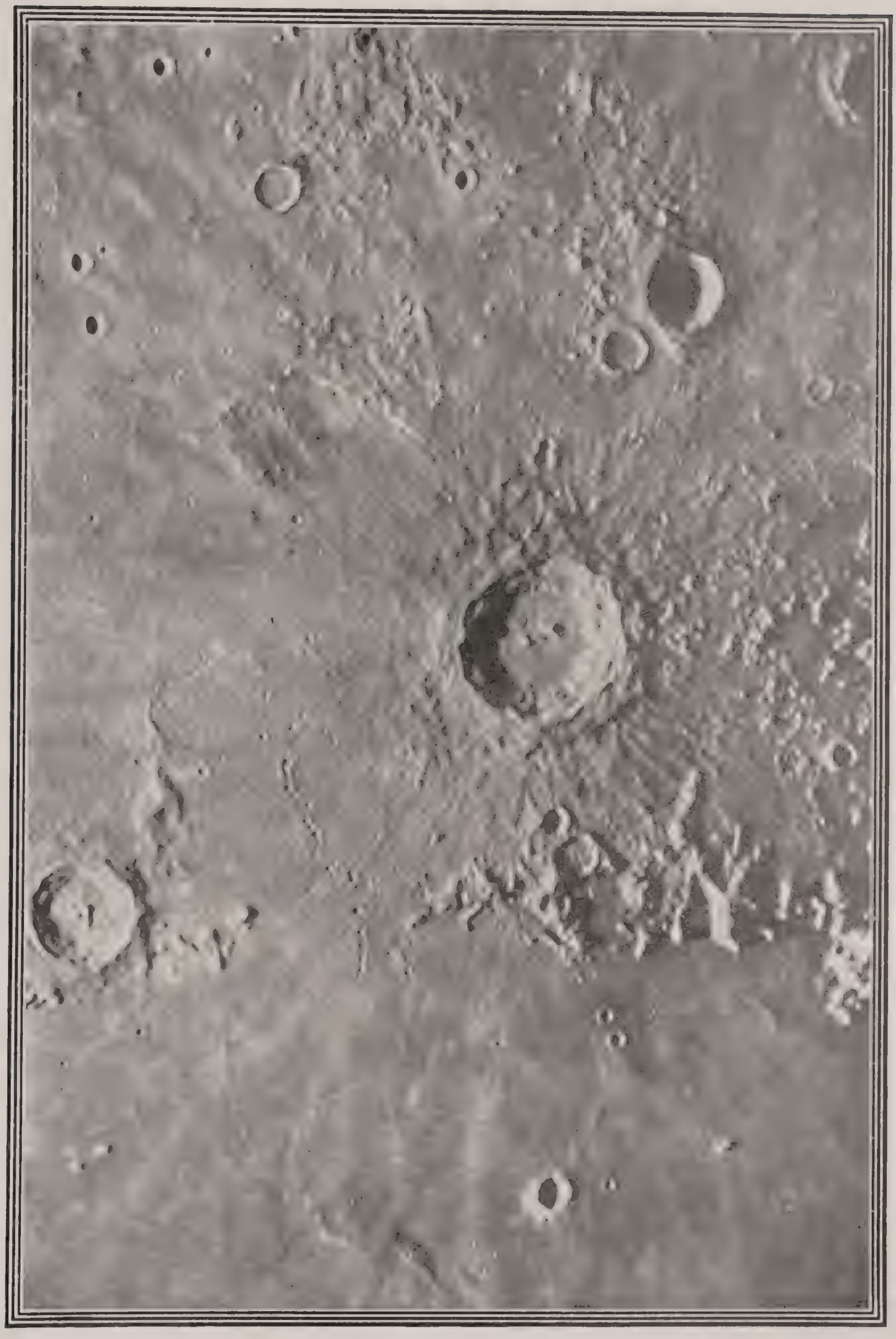
HOW THE MOON CAUSES TIDES IN THE SEA.

Why is it that twice each day the ocean seems to rise so high and that twice each day it falls so low? We cannot believe that great mountains of water are actually emptied into the ocean at high tide and afterward drawn off again; it must be that the quantity of water in the ocean stays always the same, and that for some cause much of the water is moved over the earth from one place to another. More than two centuries ago the great astronomer Newton clearly proved that this cause was principally the pull of the moon on the waters of the sea, although the pull of the sun makes small tides too.

If you will look at a map of the world you will see that all of the oceans are connected together, so that the water can easily flow from one ocean into another. We may, if we wish, think of all the water on the earth as one great ocean, and of the great continents as islands in this great Earth-ocean. Now if the earth did not turn around, the pull of the moon in the sky would heap much of the water of this ocean into a great mountain of water, exactly under itself. And as the moon is going very slowly around the earth this mound of water would be drawn around the earth too. It would always keep under the moon and so it would be nearly a month before it was dragged all the way around our world. Whenever the mound of high water reached an island or sea-coast town, there would be a high tide at that island or town. So that if the earth did not turn around there would be a high tide once each month.

But there would also be other high tides made by another mound of water on the earth. For the water would be heaped up not only at the place on the earth directly under the moon but also at the place on the exactly opposite side of the earth. This is because the moon not only pulls the water underneath it away from the earth, but it also pulls the round ball of the earth a little away from the ocean on the other side of the earth. It is as if the bed of that ocean sank down, making the water deeper. So that if the earth did not turn around there would always be two great mounds of water on it, one of them exactly under the moon and the other on the other side of the earth away from the moon. And every place on the earth would have high tide whenever one of these mounds of water reached it; that is, there would be two high tides in each month.

The earth turns around once each day and the moon moves around the earth in the same direction as the earth is turning. On account of these two motions, if we saw the moon overhead on one night it would not be overhead again until fifty and one-half minutes later on the next night. That is, the moon requires twenty-four hours and fifty and one-half minutes to move from any meridian of the earth all the way around to the same meridian again. And so the mounds of high water caused by the moon are dragged around the earth in just twenty-four hours and fifty and one-half minutes too. And as there are two mounds, there will be two high tides each day at every place on the earth just twelve hours and twenty-five minutes apart. It was this extra twenty-five minutes between the times of high water that made people



The Crater Copernicus.

sure, even many thousand years ago, that the moon in some way made the tides, but they could not explain how it was done. It was not until the great law of gravitation was discovered by the immortal Newton that all was made clear.

The mounds of high water are not really exactly under the moon. They are dragged around the earth, moving much more rapidly in deep water than in shallow water, and sometimes striking a continent and running for thousands of miles along its coast. So that high water reaches different places on the earth at very different times. But after one high tide it will always be just twelve hours and twenty-five minutes until the next high tide, except in some places where river or wind currents may cause a little hastening or delay.

The pull of the sun causes tides just as the pull of the moon does, but the sun is so far away that its tides are much smaller. When the sun and moon are in a line, which happens whenever the moon is new or full, the tides are very large; these are called Spring tides. When the moon is half full the tides are smallest; these are called Neap tides. Spring tides may be three times as high as Neap tides.

The great mounds of water which are dragged around our earth put a brake on it and make it turn more slowly, exactly as a turning wheel would be slowly stopped if you should press against it. And so we believe that the day is now longer than it used to be. And when the moon was young, the great tides which were raised on it by the pull of our earth kept making it turn more and more slowly until at last it has come to keep the same face always toward the earth. If we could have stood on the earth many ages ago, probably long before our world grew solid, we would have seen the moon slowly turning and we could have looked at the side of it which is now forever turned away from us.

CHAPTER X.

Eclipses of the Sun and Moon.

WHEN THE SUN IS HIDDEN.

A TOTAL eclipse of the sun is the most striking and awe-inspiring sight which we who are on the earth ever witness. On some clear day we suddenly feel that the light poured out by our brilliant sun is growing less; it is as if a haze or light cloud was passing over the sky, but if we glance upward we see that no haze or cloud is there. And it steadily grows darker and darker. The sun is being hidden by some body; instead of looking round, it has the shape of a small, very bright crescent, and this crescent keeps getting narrower and narrower. At last it disappears entirely, and in front of our sun there seems to hang an inky-black ball which shuts off its light from us. We see the brighter stars shining in the sky, with the bright planets Mercury and Venus among them. Night seems to have come suddenly in the day-time and in the dim light everything looks strange and unnatural. A few moments later the edge of the sun flashes out from behind the black body. The stars at once disappear, the black body moves steadily off from the sun, it grows brighter and brighter, and soon it is full day-light again and the eclipse is over.

In the early days when men knew less about astronomy than they do now this wonderful sight filled them with the greatest fear and terror. They thought it showed the wrath of heaven and that it meant that terrible wars or diseases or other dreadful troubles were to visit the earth. Even now an eclipse brings extreme fright and dread to whole nations of people. Many of the Hindus believe that the sun grows dark because a great dragon is eating it. So when they see an eclipse begin they rush out of doors, screaming and beating gongs and making all the noise they can to drive the monster away.

The strange darkness which comes in the daytime fills even animals with uneasiness. Birds which have been singing grow quite silent and show signs of disquiet; deer and many other animals run back and forth in alarm; bats fly about as if it were night-time, and bees leave the fields and return to their hives. During one eclipse, cattle were seen to arrange themselves in a circle with their horns outward to keep off the unknown danger which they felt was approaching them.

The Sun during an Eclipse in 1887, as it appeared when seen from Vienna.

It is no wonder that great terror is caused by so strange a thing. To see our bright sun losing more and more of its light, until finally it looks entirely dark, is the most startling sight that can ever come to us. But now it no longer causes us any fear. We know just why eclipses come and we can tell when they will come.

Even if one certain eclipse is not to happen until one hundred years from now, we can tell just when it will begin and when it will end and how it will look to people in different parts of the world. And we know that on the particular day and at a certain time it will as surely come as if we could live to see it.

We now think of eclipses as most beautiful and wonderful sights, and astronomers make long journeys over the earth to look at them. In this place, as in many others, we find that as we learn more our fears disappear. We no longer see in eclipses a sign of the anger of a terrible and all-powerful being, but they tell us most clearly of the wonderful harmony and perfection of the laws which govern the heavenly bodies in their motions.

HOW AN ECLIPSE OF THE SUN IS CAUSED.

We have seen that the sun is a wonderfully large body a very great distance away from the earth, and that the moon is a little round world only one four-hundredth part as far away as the sun is. Although the moon is so very much smaller than the sun, yet because it is so much nearer to us it looks almost exactly as large. Sometimes the moon is nearer to the earth than usual and then it looks a little larger than the sun, and sometimes it is a little farther away and then the disc of the moon seems a very little smaller than the round disc of the sun.

We know how the moon is always moving around the earth, but if we should watch carefully we would see that the path which it follows among the stars is always changing. If tonight we see it pass between us and some little group of stars, then twenty-seven days from tonight, when it has gone all the way around the sky, we will see it pass either a little above or below the stars which it covered up before. As our moon moves all the way around the sky once each month, it is clear that once in each month it must pass from the west to the east of the sun. If we could see the moon and the sun together in the sky at this time we would usually see that the path of the moon did not lie exactly across the round sun but passed a little above or below it. But sometimes the slowly changing path does lie exactly across the center of the sun; then we see our round, dark moon move exactly in front of the sun and there is an eclipse of the sun.

So we see that an eclipse of the sun is made because our moon sometimes gets exactly between us and the sun and hides its light from us. If the moon is so near the earth that it looks larger than the sun it may entirely cover it up; for a few minutes we will then not see the sun at all and the eclipse will be a wonderful Total Eclipse. If the moon is a little farther away from us its round disc will look a little smaller than the disc of the sun and then, even when the center of the moon seems exactly on the center of the sun, the sun will not be all covered up. All around the edge of the black moon we will then see a very brilliant ring of sunlight. Such an eclipse is called an Annular Eclipse, or a Ring Eclipse. The path of the moon may not lie across the center of the sun, and the moon as it moves along its path may only hide a part of the sun from us. We then have what is called a Partial Eclipse. Of all these different kinds of eclipses a total eclipse is very much the most wonderful and interesting. This is because the sun is so very bright that if there is the least little part of it which is not covered by the moon we will still have bright daylight; it is only when, as in a total eclipse, it is all hidden that darkness falls and the stars come out.

The next total eclipses which may be seen in the United States will occur as follows:

June 8, 1918: can be seen in many places in the states lying between Oregon and Florida.

Sept. 10, 1923: can be seen from California to Texas.

Jan. 24, 1925: can be seen from Ontario, Quebec, and Maine.

Aug. 31, 1932: can be seen from Keewatin, Ungava, Ontario, Quebec and Maine.

On these days the sun when viewed from the places given will be hidden by the moon, that is, the eclipse will be total. But beside these there will be very many partial eclipses, that is, eclipses in which only a part of the sun is hidden by the moon. Nearly every year an observer at any place may see at least one partial eclipse. The days of each year on which partial eclipses occur may be found given in any almanac.

HOW THE MOON'S SHADOW SWEEPS OVER THE EARTH.

As the moon is a round, dark body on which the sun is shining it must cast a shadow, just as any other body in the sunshine would do. The moon's shadow always stretches from the moon in a direction exactly away from the sun; it is round, and at the moon it is exactly as large as the moon is, but farther away from the moon it grows smaller and smaller and finally ends in a point. The distance from the moon to the farthest point of the shadow is almost the same as the distance from the moon to the earth. Sometimes the moon is nearer the earth than usual and the shadow may reach many thousand miles beyond the earth, and sometimes the moon is farther away and the earth is altogether beyond the end of the shadow.

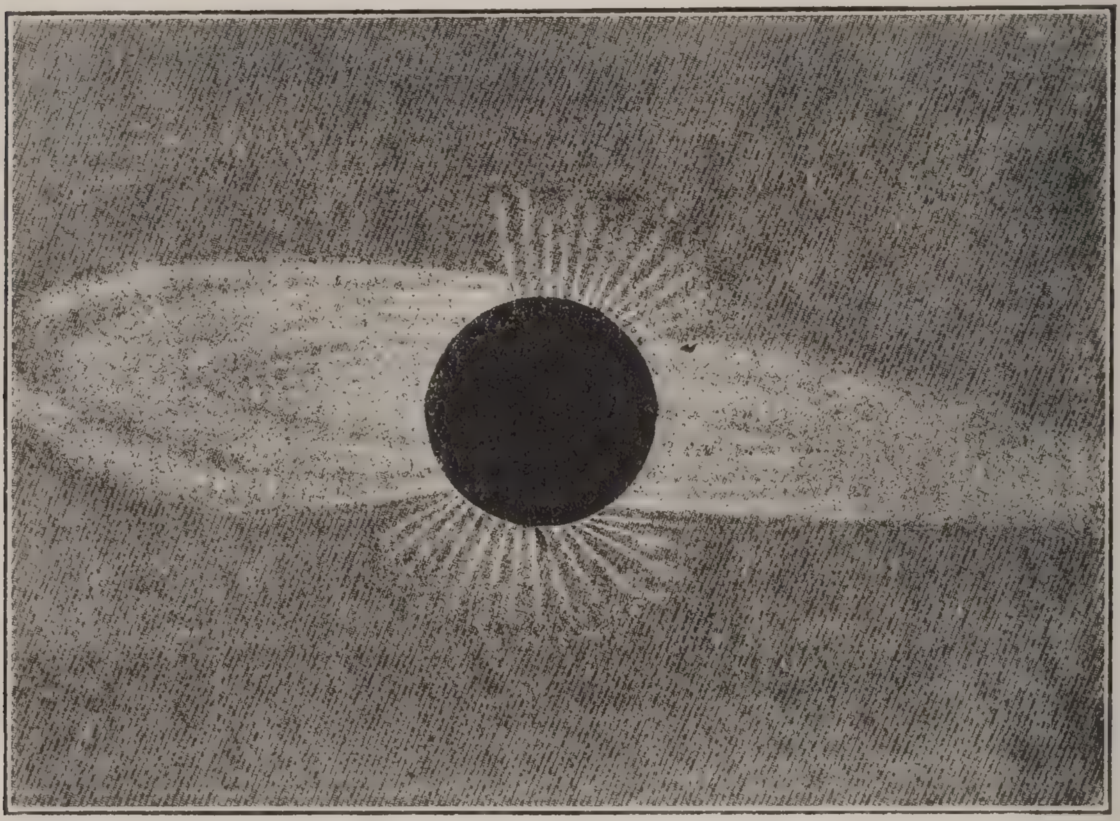
Our moon is moving around and around the earth in its path faster than two thousand miles an hour, and as it moves it always carries its great shadow with it. At the time of a total eclipse the end of the shadow strikes the earth and moves very rapidly over it from west to east. If we could stand on some other world and look at our earth at such a time we would see the little round, black moon-shadow suddenly appear on its edge, move steadily across the turning earth, and finally pass off at the other edge. The people in any part of the earth would be in darkness while the shadow was passing over them; they would then see the sun entirely hidden by the moon.

If one stands on a mountain or other high place he can see the shadow rushing toward him before the total eclipse begins. This is a wonderful sight. As he waits, he suddenly sees a darkness appear, far away over the country, which looks much like a heavy thunder-storm. But it comes toward him with terrible swiftness. In a very few seconds it covers him, and the total eclipse has begun. For a time which can never be more than eight minutes, and is generally very much less, he remains in the shadow. Then suddenly it grows bright daylight where he is, he sees the black shadow rushing away from him, and the wonderful experience is over.

The shadow of the moon sometimes sweeps across one part of the earth and sometimes across another. It is only from places in its narrow path that the sun is entirely hidden; observers who are near the path but not exactly in it see the sun only partly covered by the moon. When astronomers have found by calculation just where the path will lie in any eclipse they form expeditions which go to all parts of the earth to get inside it. There they set up telescopes and make many observations; among other things they take hundreds or even thousands of photographs during the very few moments when the sun is hidden.

THE CORONA OF THE SUN.

As soon as the sun is all covered, a beautiful, greenish "Crown of Light" flashes out all around the black ball of the moon. It is brightest near the sun, and here the sky is covered with a uniform, greenish ring of light, but it fades away as we follow it outward and finally changes into long, narrow streamers. The streamers are sometimes nine millions of miles long, and stretch out over the sky a distance more than ten times as far as the distance across the sun itself. At the base of this beautiful, bright light we see the deep red clouds which surround the sun, and the whole strange figure shining out in the sky forms one of the most striking and interesting sights ever witnessed by men.



The Corona of the Sun.

For a long time it was not known what this light was. But as soon as men learned how to photograph it, it was found that it must belong to the sun itself and not be near the moon nor in our air. For the dark moon was seen moving in front of it, covering up one part of it after another just as it covers up the sun, and this showed clearly that it must lie at a great distance beyond the moon. When its light was studied from the bright lines in its little color strip, men found that it was partly made of glowing hydrogen gas, and this showed also that it could not be near our earth nor near the cold moon. Beside the lines in the spectrum made by hydrogen, there are other bright lines which so far we cannot make by heating anything which we have found on our earth. The beautiful greenish light is called the Corona of the sun, and so they have named the unknown thing Coronium. Probably some day we will find Coronium on the earth just as we found Helium here twenty-eight years after it was found on the sun.

The little color strip tells us that the corona is not only made out of glowing hydrogen and coronium, but that it is also filled with very little solid particles which reflect the light of the sun. Altogether it is very light, probably thousands of times lighter than our air; the very little particles are probably much smaller than the particles of dust which float in our air, and together with the lightest gases they have been driven away to an immense distance by the great, hot sun. The shape of the corona is always changing and its streamers are sometimes strangely curved and twined together.

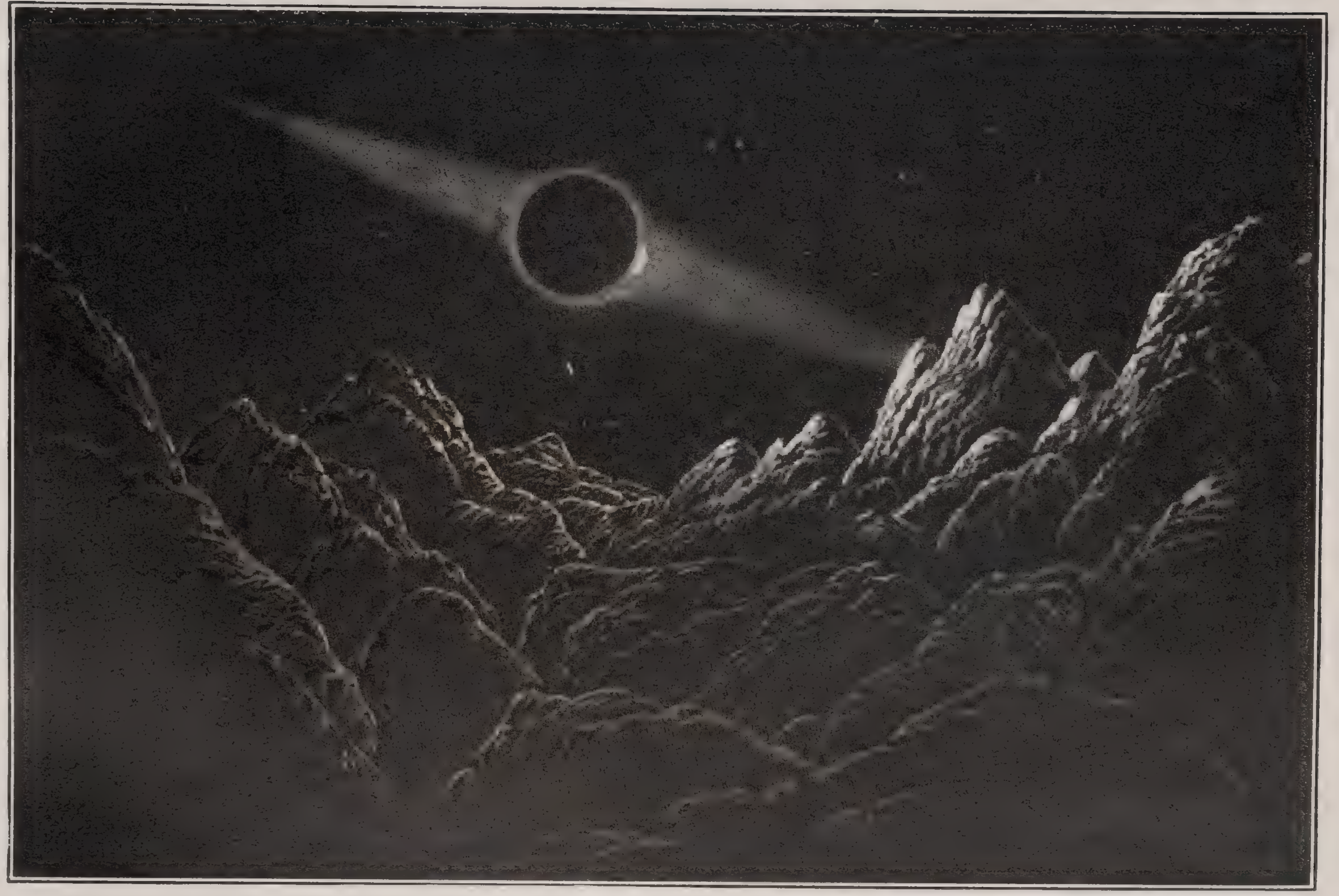
It is principally to study this wonderful bright cloud that astronomers go to distant parts of the world and observe eclipses. For although the light of the corona is more than twice as bright as the light of the full moon, yet the sun is so wonderfully much brighter that we can never see it except when the sun is hidden. The sun is hidden for so short a time that all the times when men have looked at the corona added together do not amount to more than two hours. Yet we already have thousands of beautiful photographs of it, the careful study of which is one of the most interesting parts of astronomy.

THE EARTH'S GREAT SHADOW.

Just as the moon is always attended by a round shadow which points exactly away from the sun, so there is a great shadow stretching out into space which is made by our earth. The earth's shadow is of just the same shape as the shadow of the moon, but because our earth is so much larger than the moon its shadow is larger. Where it rests on the earth it is eight thousand miles through; it grows smaller and smaller until it ends in a point, but the point which marks its end is more than eight hundred and fifty thousand miles away from the earth. The turning earth brings one country after another into the shadow, and as long as any land remains inside of it the light of the sun is cut off from that land and it has night. In the same way, from any point within the shadow the sun cannot be seen because it is hidden behind the dark earth.

As the shadow is almost four times longer than the distance from the earth to the moon it must sometimes happen that our moon will pass inside of it. At the place where the moon moves into the shadow it is nearly five thousand, seven hundred miles through, and the moon may be entirely hidden within it for two hours. An eclipse of the moon may therefore last very much longer than an eclipse of the sun; indeed the time from when the moon first begins to enter the shadow until it has passed entirely through it may be so much as four hours. And as all of the people on the dark half of the earth can see the moon at this time, they can watch its light being slowly cut off. It is because all the people on one-half of the earth can see them at the same time that we see eclipses of the moon much more often than we do eclipses of the sun. There are really more of the last than there are of the first, but only those people who happen to be in the little narrow path made on the earth by the moon's shadow can see them.

If we could see the great, black shadow of the earth stretching out toward the stars we would see the moon pass it in its journey around the heavens once every month. Generally the moon would pass above or below the shadow and sometimes it would so nearly miss it that only the upper or lower part of the moon would



The sun as it would look to an observer watching it from the moon at the time when the earth was passing between the moon and the sun. The large dark body is the earth, the red ring is our air, lighted by sunshine, and the light about the sun is the zodiacal light.

be darkened. The eclipse would then be what is called a Partial Eclipse. As the shadow is always exactly opposite the sun it follows that when the moon is near the shadow it is opposite the sun too. But when the moon is opposite the sun it is a full moon, and this is why we never see the moon eclipsed except when it is a round, full moon.

WHAT IS SEEN WHEN THE MOON IS DARKENED.

As the moon moves slowly eastward around the sky, its front or eastern edge will reach the shadow first, and our bright, round moon will then look as if a narrow piece of it had been cut off. From this time more and more of it will slowly disappear until finally, about one hour after the eclipse began, all of the bright moon that is left will be a narrow little strip of light at the western edge. Then this will disappear in its turn as the moon passes entirely within the shadow. The earth's shadow is so large that its dark edge seems only a little curved when we see it lying across the bright moon. At no time does our satellite have the shape of a crescent, but instead it has an appearance which seems to us strange and unnatural, as if pieces of it were being sliced away. It is no wonder that savage people think that at such a time some monster is eating up the moon.

Although the edge of the shadow which we see lying across the bright moon is almost a straight line, yet it is not perfectly straight. No matter where the moon enters or leaves it, its edge is curved just enough to show that it is part of a circle about five thousand and seven hundred miles across. This is very important, because it shows us that the shadow of our earth is always round. And we know that our turning earth could not always throw a round shadow unless it itself was a round world. There are very many other ways in which we can show that our world is round, but this is the clearest way. Everyone who sees how round the shadow is can understand why our earth must be round too.

Even when the moon is entirely inside of the shadow, we can generally see it. It is then generally very faint and of a reddish or coppery color, although sometimes it is covered with greenish areas. This is because even inside of the shadow all of the sun's light is not cut off by the earth. At this time an observer on the moon would see a brilliant ring of light all around our earth which would be our air lighted up by sunshine. It might look to him of a bright red color, or it might be reddish in some parts and yellowish or greenish in others. It is the sunlight passing through this air which lights up the moon when it is inside the shadow and gives it such a strange color. Sometimes it is cloudy all around the rim of the earth so that no sunlight can pass through our air and then as soon as the moon gets within the shadow it entirely disappears.

WHAT IS FOUND FROM ECLIPSES OF THE MOON.

Eclipses of the moon are not nearly so important as those of the sun and yet there are many interesting things that can be found out from them. For instance the heat which the moon pours out when it is not in sunshine can be measured, and in this way we can find that our little attendant is very cold indeed. Beside this we can study the faint light which falls on the moon from our own air and so learn what our atmosphere is made of. And by watching the faintly shining moon pass in front of the little faint stars along its path we can find out that it has no air around it and also just how large it is. We see the stars shining brightly until the moon passes over them; they are not at all hidden by the shadow of the earth, because this is not nearly long enough to reach to the stars.

Astronomers can not only tell when eclipses are going to happen in the years to come, but they also know on just what days our moon was darkened in the years which are past. From this they can often tell the exact time when important things happened if there was an eclipse at about the same time. For example, the early writers tell of an eclipse which was seen a few weeks before Herod died; astronomers know that the moon was eclipsed on March 13, 4 B. C., so that Herod certainly died a few weeks later. When Christopher Columbus was shipwrecked on the island of Jamaica and the natives would not bring his men anything to eat he told them that to punish them he would make their moon hide herself that night and put on a dreadfully dark and threatening aspect. As soon as the eclipse began the natives were greatly frightened and at once began to bring him all that he needed. As they know just how the moon is moving, astronomers know that all this happened on the night of March 1, 1504, nearly twelve years after Columbus discovered America.

CHAPTER XI.

Mars, the Red Planet.

THE MOST INTERESTING WORLD OF ALL.

ALMOST fifty millions of miles beyond the path of the earth, a round, reddish world is moving about the sun which has aroused more general interest and has been more talked about than all of the other worlds put together. This little world is the planet Mars, a round, solid world like our own, and one which has days and nights and seasons, very much as our world has.

Yet in many ways Mars is not so much like our earth as Venus is. In the first place, it is very much smaller; the distance through it is only four thousand two hundred and thirty miles, while the distance through Venus or the earth, (which are of almost exactly the same size), is nearly twice as much as this. And while both Venus and the earth are surrounded by heavy atmospheres, the atmosphere of Mars is very much lighter. There are almost never any clouds in the sky there, and there is probably never the least rain. It would be very much harder for us to breathe in the air of Mars than on the tops of the very highest mountains on the earth.

Why is it that Mars is studied so much more than Venus, and why do we know so much more about it? It is simply because we can see what there is on Mars so much more clearly. The outer world is never so near us as Venus sometimes is, but there is a great difference between the positions of the two worlds when nearest the earth. When Venus is nearest us it lies between our earth and the sun; the dark half of the planet is therefore turned toward us and we cannot see what there is on it. For many days before and after this time Venus is a very narrow crescent on which almost no details can be made out. So that the nearer Venus draws to the earth the less of it can we see.

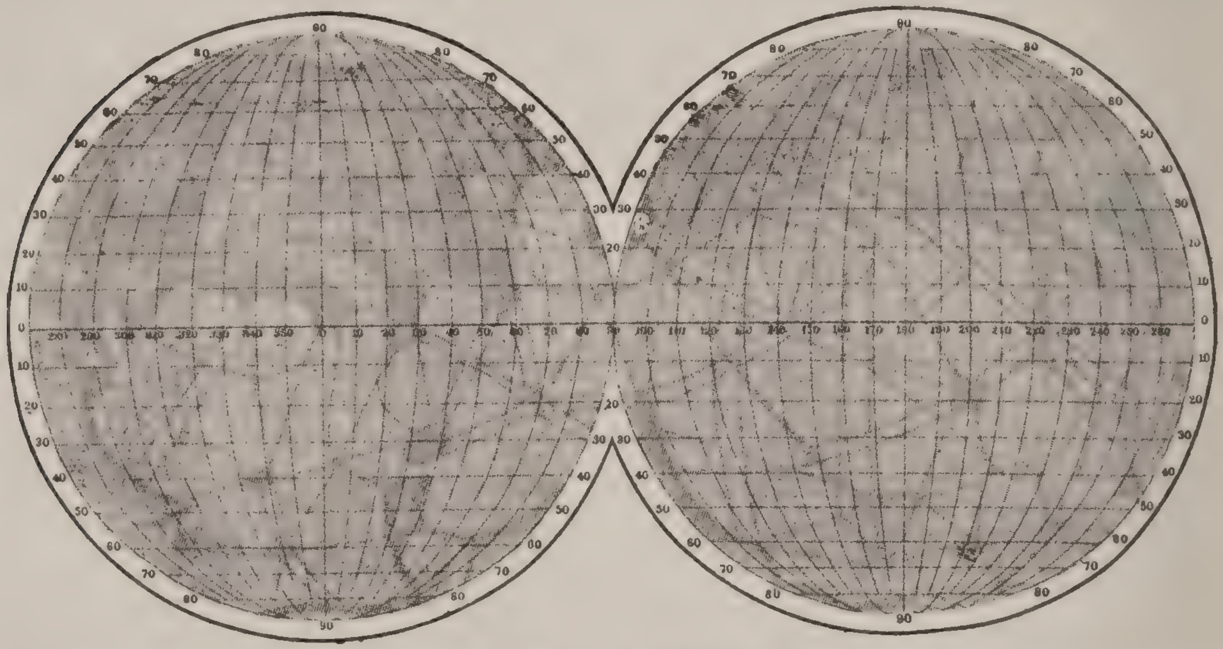
With the planet Mars, it is just the opposite. This world is moving around the sun in a nearly round path, just as the earth is doing, but the path of Mars is larger than the path of the earth and lies outside of it. When the two worlds are nearest together the earth will be between Mars and the sun; we will then look full on the sun-lit half of the little world and have a beautiful view of it. And there are never any clouds in the skies of Mars to hide its surface from us. All night long we can study the markings on our neighboring world, every little while seeing some new little detail, as our own air for a few moments becomes more quiet or more clear than usual.

On no solid world can we see so much that is of interest as on Mars, and there is no other that we can see so clearly except our moon. But Mars is very much more interesting to us than the moon is. On the moon there is no air and no water; it is a still, dead world on which all changes ceased many ages ago. But Mars is still alive. There is a wealth of interesting markings on it and in many of these there are changes going on all the time. Winter succeeds summer, just as it does on the earth, and in the winter season much of the planet looks quite different than in the summer.

Yet though we can see so much there is still a very great deal about this world that we do not know. We do not know what many of the things that we see really are, nor do we know very clearly what the world would look like to us if we could visit it. It seems probable that it is a dry and desert world, with no high mountains, no volcanoes, and no large lakes or seas on it, but of this we are by no means sure. We do not know how warm it is, and most important of all, we do not know how heavy its atmosphere is, nor what it is made of. But astronomers are studying all these things, and many others, and some day we will know more about them.

THE LARGER MARKINGS WHICH WE SEE ON MARS.

As soon as we look at Mars with a telescope we see where its red color comes from. The greater part of its surface is of a reddish color, in some places almost a rose red and in others no more than a deep yellow. The large reddish areas have definite shapes and edges, just as the continents on our earth do; they cover almost all of the northern half of the planet, but there are many large masses in the southern half also.



A MAP OF MARS.

The fine, straight lines are the so-called "Canals". The darker parts are greenish in the telescope, and the lighter ones are yellow or rose colored.

Nearly all of the rest of the planet is of a greenish color. The greenish parts surround the red ones, just as the seas of the earth surround our islands and continents, but the whole surface of Mars is divided into much smaller parts than the surface of the earth is. There are no reddish areas nearly so large as

America or Asia, but the red and green parts are mingled together.

Astronomers used to think that the red areas are land and the greenish ones are water, and that the whole surface of Mars resembles a great archipelago. One great bay, shaped much like the Bay of Bengal, is named the Syrtis Major, which means the Great Strait; a large area which is almost exactly round was called the Lake of the Sun, while the largest of all is named the South Sea. These early names have not been changed, although we now believe that the greenish areas are not water, and in fact that there is very little water at all to be found on Mars.

Even in a rather small telescope the observer may see clearly the larger of the red and greenish regions which cover Mars. And if he watches this most interesting country for even a very short time he will see that all the markings are moving. The world is turning around on an axis just as our world does, and almost exactly as fast; it turns completely around in twenty-four hours, thirty-seven minutes, and twenty-two and seven-tenths seconds, so that the days and nights on this little world are each only about a quarter of an hour longer than with us.

It is very interesting to watch one marking after another disappear around the edge of the planet and to see other regions brought around the other edge into daylight as the planet slowly turns. In the course of twelve hours the half of the world which had day is entirely replaced by the half which had night, so that by waiting, all sides of the planet will be turned toward us in time, and we can see and study any part we wish.

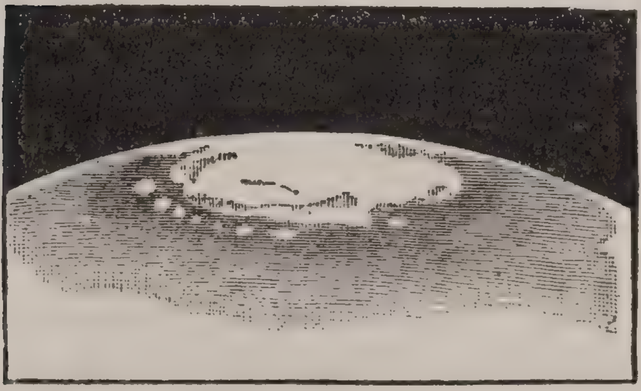
The path which Mars follows around the sun is much larger than the path of our earth, and the little planet moves along in its path more slowly than we do in ours. It therefore takes Mars six hundred and eighty-seven days to move all the way around the sun;

that is, the year on Mars is six hundred and eighty-seven days long. The countries on the red planet have spring, summer, autumn, and winter just as we do, but each of these seasons is nearly twice as long as with us.

WHAT HAPPENS IN THE POLAR REGIONS OF THE RED PLANET.

Around each of the poles of Mars we see a wonderfully interesting thing. This is a large, brilliantly white region, looking exactly as if the country here was all covered with ice and snow. If an astronomer could go to Mars and look at our earth he would see just the same thing here. During the long northern winter he would see our northern ice and snow spreading so as to cover more and more of our earth, even reaching down past Hudson Bay to the United States itself. During summer the white area would grow much smaller, but it would never disappear entirely, because the ice and snow in the polar regions of the earth never all melt away.

If we watch the polar cap of Mars during the approach of winter we will see that it is continually getting larger. It does not merely swell in size gradually, but sometimes in only a few hours whole areas, sometimes as large as the whole United States, become white which were dark before. It looks exactly as if over those areas there had been a fall of snow; and as winter goes on the snowfalls occur farther and farther away from the pole until a large region of the planet is covered.



The South Polar cap of Mars, as seen in September, 1877.

With the coming of warm weather the polar cap begins to disappear. It at first merely shrinks in size but afterward it may change its shape much more irregularly. The edge becomes notched; some of the notches may increase into long, black rifts which push backward into the cap, until they finally may even break it up into several separate white patches. The black rifts may mark the positions of valleys and the white patches may be the snow which is left on higher ground. Sometimes a few cold days seem to come; the breaking up stops for a time and the cap may even get larger, but it is too late in the season for cold weather to last long and the new growth soon disappears. And so the polar cap seems to gradually melt away; by late summer it is very small indeed, and it has even been seen to entirely disappear. This seems very strange to us; around the poles of our earth there are thousands of square miles of ice and snow which never melt, but on Mars there is sometimes no ice or snow in the polar regions at all.

What are these strange and most interesting polar caps? Is it really ice and snow which we see melting away as the Martian weather grows warmer? If so, it is a thing of most wonderful interest to us, for it tells us clearly that this far distant world is almost like our own. If it is really ice and snow, Mars must be a little warmer than our world, since our snow here never all melts away. It must have an atmosphere also, which, like our own, is filled with moisture. And we can hardly doubt that such a warm world would be swarming with life.

But very unfortunately we cannot certainly tell whether the polar caps are made of ice and snow or not. They look as if they were, and they act as if they were, but we cannot be sure. They may be some quite different substance, such as never covers the ground in this way on our earth. It is true that this is not likely, but we are not certain that it is not so, and in a matter of such very great interest to us as this, it is of the highest importance that we should be entirely certain.

IS THE AIR OF MARS WET?

Almost all of the air around our earth is very wet; it is only in a few places in the world, such as in the great deserts, that our air is dry: it is difficult for animals or plants to live in such places. If the white areas around the poles of Mars are really ice and snow the air of Mars must be made wet by them. And if we can find that the air is wet, then we can be sure that Mars is a warm world with water on it, very much like our own world.

We have seen how we can make a little color-strip, or spectrum, with sunlight, and how by studying this little spectrum we can tell just what the sun is made of. And we also saw that if the little beam of sunlight which makes the spectrum has passed through any atmosphere on its journey to us we can tell just what the atmosphere is made of too. Now Mars is really a dark world, just as our own world is, and the light which comes from it to us is really sunlight which passed through the air of Mars, was reflected from the surface, passed again through the air of the planet, and finally came to our earth. So if there is water in the air of Mars will not a little spectrum of Mars' light show us clearly that the sunlight has passed through wet air?

Astronomers have made many hundreds of little color strips of Mars-light to try and answer this question. But there is always one great trouble which they meet with. The little beam of light after leaving Mars must pass through the great ocean of air which is around our earth before it can reach us who are at the bottom. And our air is always wet. So in the little color strip there are always the dark lines made by wet air, but these may entirely come from our air and not at all from the air of Mars. The only way to be sure is to compare a color strip from Mars with one made by sunlight which has gone through our air and no other.

As it is known that there is no air on the moon, astronomers usually compare Mars-light with moonlight. Both little beams of light have come through our air, but one of them has passed twice through the air of Mars besides. If any water is in this air, then the lines of the second little color strip will be darker and stronger than those of the first. But unfortunately our instruments seem to be not yet large and powerful enough to show any difference. Men are working on this now, and on any day we may read in the papers that water on Mars has been discovered. And on that day we will for the first time be perfectly sure that Mars is a warm world like our own.

Even if the air of Mars is wet it is not nearly so wet as our own air. There is so much water in the air of the earth that it often condenses into clouds; and sometimes our air gets so full of water that it can no longer hold it, and it falls to the earth in rain. The air of Mars is very clear. Sometimes a thin fog or mist is seen which may cover a large area of the planet but there are no heavy, dense clouds as there are here. Sometimes too we see what seem to be clouds of dust which are blown to a great height by the wind. Altogether it seems very probable that Mars is a quite warm world, on which there is ice and snow in winter time; that it is a dry world on which there are very few clouds and probably no rain, and that much of the planet is a dry and desert region.

HOW A WORLD MAY BE KEPT WARM.

When we were telling about the sun we explained how all the warmth of our earth comes from that great hot body, and how if the earth were moved much farther away from the sun it would be a much colder world than it is. Now the warmth of Mars must come from the sun too, and Mars is almost fifty millions of miles farther away from the sun than we are. How then is it possible that Mars should be kept as warm and perhaps warmer than our earth?

Before we answer this question let us first see how it is that our earth is kept warm. All around the earth there is a deep ocean of air which acts just as a blanket to keep the earth from losing its heat. The heat of the sun passes easily through this air and warms the earth, but it is a strange fact that the heat from the warmed earth can not easily pass away through the air again. It is in just the same way that the inside of a hot-bed is kept so much warmer than the outside. The heat from the sun passes easily through the glasses over the hot-bed and warms the ground underneath, but the warmth of the ground cannot easily pass through the glass again. The box covered with glass keeps in the heat from the sun, so that a hot-bed may sometimes become very warm even on a cold winter day.

The air protects our earth just as the glass protects the hot-bed. If there was no air, the moment the sun set and it became dark in any part of the world, that part would grow so very cold that every living thing on it would be killed.

The deep atmosphere around the earth is principally made out of two gases called Oxygen and Nitrogen. But there are also many other things in it, and one of the most important of these is a gas made out of Carbon and Oxygen mixed together which is called Carbon Dioxide. This strange gas is a deadly poison to animals, but nearly all plants would die without it. Plants are largely made out of carbon; when the carbon dioxide passes into the pores of their leaves they are able in some wonderful way to draw the carbon out of it, and with this they build themselves up; and they let the oxygen go back into the air again, and this all animals breathe. Thus the animals and plants of the earth depend upon one another in a wonderful way. All animals are always breathing the oxygen out of the air and filling it with carbon dioxide, but the plants are continually changing this poisonous gas into carbon and oxygen and pouring the last out into the air to make it pure again.

The air is like a great warm blanket around the earth, but how warm a blanket it is depends on what it is made of. There is only a very little carbon dioxide in our air, but if this were taken away, the air could not keep the warmth of the earth in nearly so well, and the whole world would grow much colder. But if there was a little more carbon dioxide in the air than there really is, less of the earth's heat would escape through the air and it would grow much warmer.

Mars is so far away from the sun that it receives less than half as much heat as we do. If the air around it were exactly like our own it would probably not be much warmer than thirty or forty degrees below zero; that is, it would be about as cold as the polar regions of the earth. But as we have seen, we cannot tell what the atmosphere of Mars is made of. It need be only a little different from our own to make it a much better blanket than our air is. And if this is so, it is quite possible that this little world is warmer than ours even though it is so much farther away from the sun.

THE CANALS OF MARS.

The very strangest thing of all about this little world was the discovery, almost forty years ago, that there are a great many faint, narrow, greenish little bands called Canals, which stretch across it in every direction. These canals are almost perfectly straight; they are seen both in the red and in the greenish parts of the planet, but those in the red part always join two greenish areas, or else they join a greenish area with another canal; they never begin or end in a reddish region. Sometimes many of these strange lines meet together in one point like the spokes of a wheel, and then there is always a little round, greenish area at their point of meeting. And most strange of all, many of them sometimes become double; instead of a single canal, two canals are seen side by side. These strange markings appear first near the melting polar caps. As spring advances they grow clearer and clearer, and they are seen in increasing numbers until the whole surface of the planet is covered with them, all the way down to and below the equator. Nearly two hundred canals have been observed and drawn so far.

What are these strange greenish lines? They certainly are not real canals with water in them, for they are from twenty to two hundred miles wide, and hundreds or even thousands of miles long. Many astronomers believe that they are long, narrow strips of irrigated country. They believe that the greenish parts of Mars are vegetation and that the reddish parts are desert regions; that Mars as a whole is a desert world with very little water, and that the canals have been made by intelligent beings to lead the water from the melting polar snows across the country. It is not the water courses that we see, but the strips of growing plants on each side of the canals themselves.

We do not know at all whether this explanation is the true one or not. Mars presents to us a study of the most absorbing interest. What a wonderful thing it will be if some day we surely find that there are living beings on that distant world! From that day on how intently we will watch every slightest change upon its surface! But we do not know yet. This is one of the many things in astronomy which we are still trying to learn more about.

THE TWO MOONS OF MARS AND THEIR STRANGE MOTIONS.

If we could visit Mars, we would see two little moons moving around in the sky, in what would seem to us the strangest way imaginable. The brightest one would rise in the east and climb up the sky very slowly; all day and all night, for two days and three nights, it would shine out in the sky. The stars and the sun would drift past it as they rose and set, but all night and all day long, there the moon would remain, neither rising nor setting. Yet all the time it would be very slowly working its way westward, and at last, sixty-six hours after it had risen in east, we would see it slowly sink below the ground in the west. Between the times when it rose and set it would twice go through all of its changes, from dark moon to crescent, and then to full, and finally to a dark moon again.

The second little moon would rise in the west and run so rapidly eastward across the sky that we could see it moving. If we should see it rise in the west at six o'clock in the evening it would next set in the east at half past eleven: at five o'clock the next morning it would again rise in the west and begin again its strange eastward journey around the sky. There is no other world in the whole solar system from which we could see any heavenly body rise in the west and set in the east.

The slow-moving moon is named Deimos and the other Phobos. These are the names which the ancient Greeks gave to the horses which were supposed to draw the chariot of the god of war. Phobos moves once around Mars in only seven hours and thirty-nine minutes, and as it takes Mars more than twenty-four hours to itself turn completely around, this moon rises in the west. Deimos passes around the planet in thirty hours and eighteen minutes. Phobos is only three thousand seven hundred and fifty miles away from the surface of Mars. It is so near the ground that it could never be seen by an observer in the polar regions, just as an observer near the pole of our earth could not see a balloon if it were sent up from the earth's equator. Every twelve hours Phobos passes into the shadow of Mars and is eclipsed. Both moons are very little bodies; both of them shining together do not give more than one-fiftieth part as much light as our moon does.

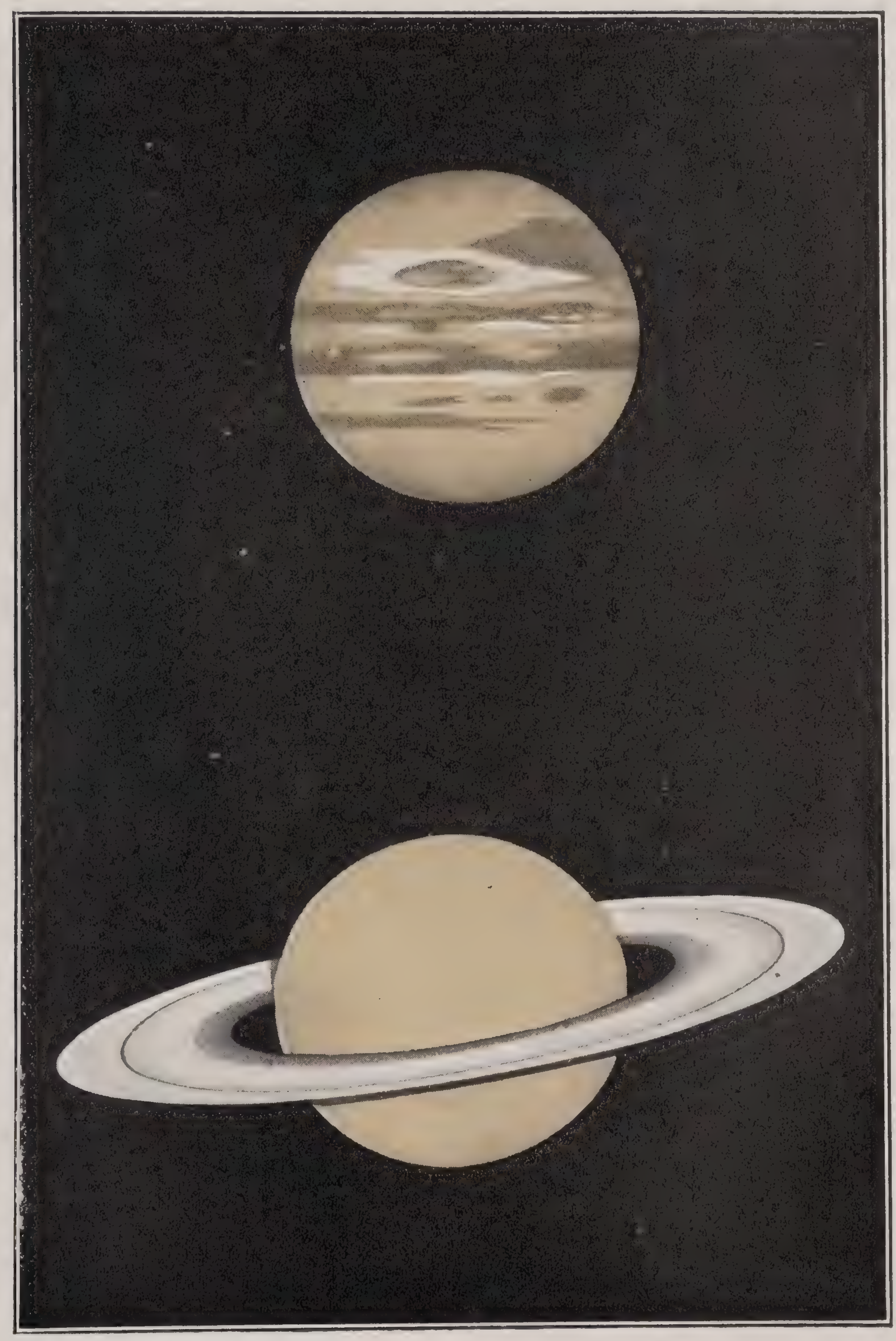
CHAPTER XII.

Jupiter, the Giant Planet.

THE GREATEST OF THE PLANETS AND ITS STRANGE FAMILY OF MOONS.

IN those regions of the solar system that lie beyond the paths of Mars and the asteroids, there are four planets so different from the earth in every way that it might be said they form a class by themselves. These strange planets are Jupiter, Saturn, Uranus, and Neptune. They are all of immense size, but Jupiter, the nearest one to the sun, outranks the rest. It is so great that if all the other planets were lumped together, with the moon thrown in, the united bulk would be less than three-fourths as large as Jupiter, and they would weigh less than one-half as much. Great as is our earth with its wide stretching continents, its immense oceans, its innumerable islands, seas and lakes, it is a small body indeed when compared with the giant planet. The distance through Jupiter is eleven times as great as the distance through the earth: there would be one hundred and nineteen times as much space for explorers to travel over upon its surface: it would outweigh three hundred planets as heavy as the earth. If Jupiter were represented by a good-sized orange, the earth, on the same scale, would be no larger than a pea.

Great size, however, is not the only peculiar thing about this strange world. The fact is, there is nothing in which it is at all like the earth. To begin with, instead of having one moon as the earth has, with alternating fortnights of moonlight and darkness, Jupiter has no less than eight moons, four of them as large as, or larger than our moon. What an amount



1. The Planet Jupiter. 2. The Planet Saturn.

of moonlight there must be there! Let us try to imagine it. As the sunset and the darkness swiftly descended upon us, perhaps we would see, just rising in the east, a full moon as large as ours: high up in the heavens there might be another not quite full, about one-half as large. We might see a third out in the west, shining as a broad crescent, also about half as large as our moon; while in the west a thin crescent, still smaller, would be just setting. On following nights we could see these four moons continuing on through change after change, each one passing through its different phases from new moon to full moon and back again to new, each in its own period, the most swiftly moving one passing entirely around the sky in only one day and eighteen hours, and the one which moves most slowly requiring sixteen and three-quarter days of our time to make the journey. Now we would see all four in the sky at once, sometimes none at all, more frequently two or three. They would pass and repass one another in the sky, furnishing an ever changing scene of strangest beauty.

Another peculiar thing would be the very many eclipses of these moons. Upon the earth an eclipse of the moon is a comparatively rare occurrence; one may happen three times in a year at most, and even then it may not be visible at the place where we happen to live. Then the eclipse, when we do see it, is a very deliberate, impressive affair. Its coming is heralded by a gradual dimming of the moon's light before it reaches the earth's shadow: then our moon spends a whole hour, more or less, in passing into the shadow, and the same time in coming out again. On Jupiter everything is different. Jupiter's moons pass through its shadow and are nearly always eclipsed every time they come round; and this, for the nearest of the four large moons means about four times in a week of our days. And whenever an eclipse occurs there, the moon's light is cut off almost at once;

it is only from four to ten or fifteen minutes after the eclipse begins until the moon is entirely dark. Then in from two to five hours the process is reversed; the moon pops out and becomes bright again in the same short time.

A VISIT TO THE GIANT PLANET.

But even before we would have a chance to notice all these strange occurrences we would be compelled to give attention to other curious experiences. First, we would find that, owing to the immense size of the planet to which we have come, everything would be greatly increased in weight. For instance, a boy who would weigh a hundred pounds on the earth would find he had gained a hundred pounds, although he would be as thin as ever. This would make walking impossible and one must lie down in sheer weariness. Suppose it were possible to organize a game of baseball there. Because of his greatly increased weight a player in merely running the bases would have to work as if he carried a heavy man on his shoulders. The bat would feel as heavy as iron, and the ball like lead. If the catcher were to try to throw the ball to second base it would hardly reach the pitcher; few balls could be batted beyond second base, while to slide to base would be a dangerous proceeding; for an ordinary drop from a standing position would do as much harm as a fall from a second story window on the earth.

We would find other things even more curious on this strange planet. While we can not be as certain of these conditions as we are of those just mentioned, still astronomers have many good reasons for believing them. In the first place, Jupiter is in a very hot condition, nearly if not entirely red hot, and possibly even turned into a vapor by its great heat. And so there can be no oceans or seas there, and, of course, there can be no plants or other forms of living things on this world. The waters must be in the form of vapor, a vast blanket of clouds perhaps thousands of miles deep, and the planet itself a much smaller sphere than it appears to be, hidden away in the center of this cloudy wrapping, if indeed there is any little solid core to this world at all.

There are reasons also for thinking that there are winds on Jupiter compared to which the most devastating hurricane here would be as an evening breeze in June. The weather man tells us, for instance, that in a certain tornado of which he has received reports, the wind blew eighty miles an hour: it blew away houses, tore up trees, and devastated towns and cities. But on Jupiter we would encounter as usual things tempests in which the clouds and winds sweep onward two hundred miles an hour and more. In fact if we were there, and could see anything on the planet's surface, buried as it is in obscurity thousands of miles under its deep blanket of impenetrable cloud; or if we could hear the indescribable confusion as its hot contents hissed and steamed in the drenching torrents of scalding, corrosive rain falling upon them, with deafening thunders, volcanic explosions, and appalling earthquake rumblings, the dark betimes lit up by vivid lightning flashes or the lurid glow of molten lavas or red hot rocks, we would find it such a scene of appalling confusion, such a horrible pit of Tartarus, that we would gladly retreat and return to the upper regions above the clouds where at least the calm shining stars would give assurance that there was still beauty and order in the universe.

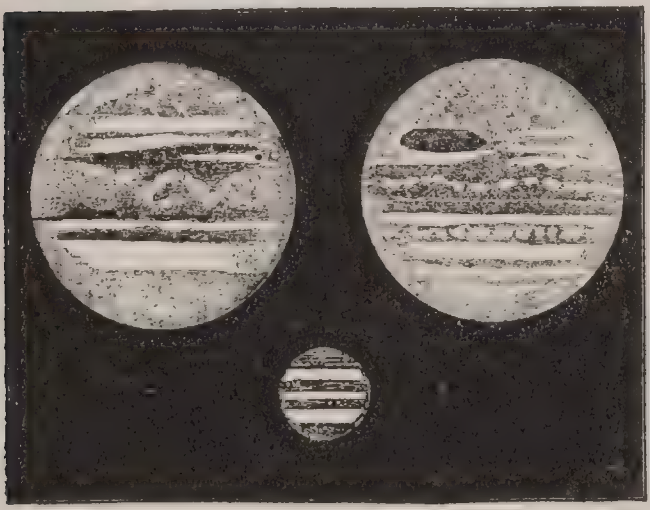
But even here new sights and strange sensations would greet us. Beside the strangeness of seeing four moons instead of one, we would be impressed with the rapid motion of the stars as they rose and set. For the day on Jupiter is less than half as long as it is upon the earth. Instead of requiring twenty-four hours to turn around once, as our earth does, Jupiter whirls round in the surprisingly short time of less than ten hours (9 hours 55 minutes). There would be five Jupiter days during the time we had been used to living through two. We would see a constellation or a moon sweep up from the east; in less than two hours and a half it would be overhead, and in five hours it would be setting in the west. The sun would behave in the same way: we would be just getting hungry for our noonday luncheon when the sun would be setting and the day over; then, by the time we were ready for the evening dinner, the sun would be rising and another day begun. On the other hand, the year on Jupiter is very long, for this planet requires no less than eleven years and ten months, or ten thousand four hundred and seventy-five of Jupiter's days, to revolve about the sun. So if we lived on Jupiter we would have delightfully short school hours, but the term would be an interminably long one with vacations few and far between.

WHAT WE SEE ON JUPITER WITH A TELESCOPE.

As we have now had our imaginary trip to Jupiter, let us study it as it appears to us on the earth. It does not require a strong telescope at all to show us many very interesting things. We remember a boy who began with a little spy-glass about two feet long and of which the larger lens was only an inch and a quarter across: he has since examined and studied the heavens with telescopes of great size and power, but he has never felt a keener pleasure than when he first propped his little glass in an east window and found that he could see the moons of Jupiter with it. There the planet was, a pretty, little, round disc with a row of four little moons looking like stars, to the right and left of it. This is the way they looked to Galileo, the astronomer who first discovered them. When on that memorable night of the seventh of January, 1610, he pointed his little "optic tube" toward the sky, and his eye caught the splendid sight of Jupiter and its moons, a new age of the world began. Then the astronomer for the first time received a new power of seeing. The telescope, at first very small and simple, has been enlarged and perfected, so that now with such monster instruments as those of the Lick and the Yerkes observatories the astronomer can see a universe millions of times as great as the one the ancient astronomers saw, and filled with marvels they never dreamed of.

Galileo's discovery of the moons of Jupiter raised a controversy, which shows very well how men who claimed to be wise used to reason in those days. The scientists of the time at once contended that there could never be more than the seven planets which everyone had seen, because seven was a perfect number, and that therefore to claim that these four more moons must be added was flying in the face of all reason. And so they said that Galileo and his telescope must certainly be in the wrong. It was not the first time that this kind of argument had been used to choke the truth, and it has not been the last. But seeing is believing, so Galileo and his little telescope finally won out. And as men began to study the wonderful system of the old Giant and his moons it occurred to them that here was really a little model of the great solar system, and so confirmation was added to the new theory of Copernicus that the sun was the center about which all the planets are revolving, just as the little moons move around the planet Jupiter.

When we look at Jupiter with a great telescope we begin to realize its real wonder and beauty. The principal thing that first strikes our attention is the beautifully colored bands, or belts, that are to be seen at all times stretched across the disc of the planet. There are generally two principal ones, one to the north and one to the south of the equator, pretty nearly where the temperate zones are on the earth. They are supposed to be great belts of cloud surrounding the planet, though astronomers are still puzzled to fully account for them. We do know, however, that they are perpetually changing: sometimes there has been but one belt and that around the equator; sometimes it has divided into two; sometimes the south belt has been broad and dark and the north belt only a narrow shadow, and again the whole surface has been broken up into many narrow belts. Sometimes a row of white spots will be streaming along the center of a dark belt, and sometimes there will be dark spots, each indicating that some tremendous activity is going on upon the distant world.



Different views of Jupiter. The upper pictures show how the Planet looks in a rather large Telescope; the second of these shows the Great Red Spot. The lower picture shows Jupiter and its four Moons as viewed in a small Telescope.

But the most remarkable thing of all is a great oval spot, brick red in color, that was first seen in the summer of 1878. Ever since then it has remained visible. The belts may change, the spots may come and go, but the Great Red Spot continues on. It has long since ceased to be red, and is now seen only with difficulty, but it is still there, and there is no telling what changes it may undergo in the future. When plainly visible it looked much like a great dirigible balloon, twenty-five thousand miles or more in length and correspondingly broad. It seemed to float in an ocean of cloud, sometimes slowly, sometimes faster, but always more slowly than the clouds that surround it; for they can be seen parting and flowing past it, like the waters of a stream past an island. Its behavior has been carefully watched through all the years it has continued, but it is still as great a mystery as ever.

The rest of the planet is also beautifully colored at times. When the eye becomes accustomed to its delicate contrasts the planet affords a truly fine sight. The belts are generally dull red, or brown, or gray, but they may sometimes appear pink or crimson, while the brighter portions may have any color from white, greenish, or bluish, to rich yellow. When the planet is seen in the early evening on a background of blue sky it becomes a most beautiful sight indeed.

HOW MEN DISCOVERED FOUR VERY FAINT ATTENDANTS OF THE GIANT PLANET.

Until recent years these four moons were supposed to form the whole of the retinue of the Giant Planet. But since the construction of the great telescopes of modern times, and since the camera has come to be used with the telescope to photograph the stars, four more moons have been discovered. The first was found by Barnard with the great telescope of the Lick Observatory on Mt. Hamilton, California. It is exceedingly minute,—estimated to be hardly more than one hundred miles through,—and it moves completely around Jupiter in less than twelve hours (11 hours 57 minutes), in a path smaller than those of any of the other moons. In fact, it is so close to Jupiter that it can be seen by us only when it is farthest away from the planet, and then only for a short time with the largest telescopes.

In January and February, 1905, the sixth and seventh moons were discovered on photographs taken at the Lick Observatory. Professor Perrine, of the Lick Observatory, was examining some negatives of the sky in the neighborhood of Jupiter when he found two minute stars that did not occur on negatives taken at other times. They were so faint that even the great telescope would not show them. But the negative had been exposed for hours, so long that even these wonderfully small points of light were able to leave their traces upon it. By comparing photographs taken at different times, their change of place was noted, their paths made out, and the two, scarcely more than a hundred miles in diameter, were received as regular members of the solar system. They have been called twins, since they are not only of nearly the same size, but also because their paths are at about the same distance from Jupiter. Of the eighth moon we do not know very much as it was only discovered in 1907. It is also exceedingly minute, in fact it was also by photography that this moon was found. It was discovered by Melotte, at the Royal Observatory of Greenwich.

These last three moons are all at great distance from the planet, the first two over six times the distance of the most remote of the large moons, and the last still farther away. They are, in fact, so different from the first four that some astronomers think they may have been wandering bodies that at some time in the past were picked up by Jupiter as it swept along in its orbit through space.

THE ECLIPSES OF JUPITER'S MOONS AND WHAT IS FOUND OUT FROM THEM.

We have spoken of the eclipses of Jupiter's moons and what strange appearances they would produce to an observer who could stand on the planet itself. But we can also see them from the earth even with a small telescope, and a most curious and interesting sight they are. To watch the moons from time to time as they sometimes darken and at other times suddenly shine out again is most interesting. At one season of the year one sees the moons only as they enter Jupiter's shadow, which is cast just a little to the side, behind the planet, while at another season one sees them only as they emerge from the shadow. At the first times we therefore only see the moons as they disappear; we can not see them as they move out of the shadow because they are then hidden from us. In the case of the two moons farthest from Jupiter, they can be seen both entering and emerging, so that the whole eclipse is visible. It is with a peculiar feeling that, on going to the telescope, you see at first four moons, but while you look, behold, one begins to fade and apparently without any cause, goes out in darkness. Or Jupiter and the sun may be in such position that the shadow falls on the other side, and it is almost startling to see the sudden appearance of a star-like moon at a point where all was darkness but a moment before.

In addition to the eclipses there are other interesting sights to be seen with a more powerful telescope. Sometimes we see the shadow of the moons passing across the planet and looking exactly like little, round, black dots, while the moons themselves appear on the round ball either preceding or following the shadow. Sometimes they look like bright spots, as they seem to move across the dark background of some belt, or at other times when the background happens to be bright they appear to us as round, dusky spots.

A peculiar interest attaches to the eclipses of Jupiter's moons from the fact that one of the most important discoveries of modern times was made while watching them. In 1675 the illustrious Danish astronomer Roemer, then a young man thirty-one years old, in the course of a great number of observations discovered the curious fact that sometimes the eclipses came sooner than his calculations showed that they should, and that sometimes they came later. He noticed, too, that when they came ahead of time the earth was always on the side of its great, round path nearest Jupiter, and that when they were behindhand the earth was on the side farthest away. Could it be that this difference, which amounted at its greatest to sixteen minutes, could be caused by the fact that it required the light of Jupiter's moons just so much time as this to cross from one side of the earth's path to the other? No one would believe it, for astronomers had always thought that the light, even from the farthest stars, flashed to us in an instant of time.

But Roemer held his ground, even though all men disagreed with him. At last it was found that light proceeds from a shining body in waves, like the waves on a pond when a pebble drops into the water, only the waves of light are inconceivably smaller. The light waves move with a speed of 182,330 miles a second. It is an interesting fact that this speed has been so accurately measured that it gives us one of the most reliable ways of finding the distance from the earth to the sun. And it is also interesting to know that the apparatus with which the speed was found was mounted, part of it at the base of the Washington monument, in Washington, D. C., and the rest across the Potomac river at Fort Myer. And so the short space of a little more than two miles between the fort and the monument was used as a yard-stick to measure the distance to the sun—a distance so great that an express train running sixty miles an hour could not transverse it in less than one hundred and seventy-five years. And yet light passes over this enormous distance in only four hundred and ninety-nine seconds, that is, in about eight and one-third minutes.

Because of the fact that it takes light a measurable time to flash from place to place, some strange things are continually happening. For instance, now and then a new star bursts out in the heavens and shines with great brilliance. In February, 1901, a star suddenly appeared in the constellation Perseus and in less than three days became one of the brightest stars in the heavens. But to say this is only to say that in February, 1901, the light of the star reached us to tell the tidings, as with the clang of a mighty fire-bell, of that stupendous conflagration. The light itself may have blazed out as much as three hundred years before. There is no star in the heavens that we see just as it seems to be at the time we are looking at it. The nearest one of all needs more than four years to reach us with its light, so that we see it tonight, not as it seems now, but as it was when its light left it four years ago.

If we might imagine some distant star of the Milky Way to have inhabitants on it with telescopes strong enough to see the people on the earth, then they would see, not the men and events of the twentieth century, but the men and events of two, three, or four hundred years ago. For the light that left our earth at that time is only now reaching them. Perhaps they would look at the battle of Bunker Hill just taking place now, or at General Wolfe dying on the plains of Abraham, or at Columbus landing on Watling's Island.

CHAPTER XIII.

Saturn, the Planet with Rings.

A WORLD SO LIGHT THAT IT WOULD FLOAT ON WATER.

FOUR hundred millions of miles beyond the orbit of Jupiter, or at nearly twice as great a distance from the sun, there is found the great, slowly moving world called Saturn. In many ways this is a planet much like Jupiter; indeed if we except its strange rings it might be called a smaller brother of the Giant Planet. But though a little smaller than Jupiter, Saturn is still of enormous size when compared with our little earth. The distance through it is more than nine times as great as the distance through our earth, and no less than seven hundred and sixty worlds as large as ours would have to be taken to make one world as large as Saturn.

But although Saturn is seven hundred and sixty times as large as our earth, it only weighs ninety-five times as much. This is only one-ninth part of what it would weigh if it were made out of the same hard, heavy rock as our earth is; we therefore say that Saturn is only one-ninth as dense as our earth. The size and weight of the two worlds may be shown very well if we select a heavy, glass marble to stand for the earth and a pine-wood ball, the size of the smallest balls of a bowling alley, to stand for Saturn. If it were possible to have an ocean of water large enough, and if Saturn and the earth could both be dropped into it, the earth would sink quickly to the bottom, while Saturn would float. Jupiter would not quite float, but like a lump of soft coal would sink very slowly.

It is because the materials of which both Saturn and Jupiter are made are so very much lighter than the materials of the earth that we are sure that these great worlds are in great part nothing but masses of very hot gasses and vapor, with perhaps a nearly or quite red-hot core at their centers, very much smaller than the planets we see in a telescope. We would expect, then, to find that Saturn is in much the same condition as we have learned that Jupiter is. Like Jupiter it is still wrapped in a great hot blanket of clouds, which in the ages to come, when the world has become solid, may form the future oceans; and, like Jupiter, its ball is encircled by a beautiful system of belts.

THE TEN MOONS OF THE RINGED PLANET.

Saturn like Jupiter is attended by a quite large family of satellites or moons. In size they range all the way from the giant Titan, which is a moon nearly twice as large as our own, down to the two babies of the family, Phœbe and Themis, which are less than one hundred miles in diameter. This family reminds one of the sun's family of planets. For just as in the solar system we see four little planets near the sun, and then a great gap filled with asteroids, and lastly the giant planets at enormous distances away, so in Saturn's system there are five small moons next the planet, then a large space—whether filled with minute bodies or not we can not tell because it is so far away—and then come at least two giant moons, Titan and Iapetus, filling positions much like those of Jupiter and Saturn in the solar system.

The story of the discovery of these moons, one after another, is only the story of how astronomers have learned to make better and better telescopes and of how they have found new ways to explore the heavens. First the telescope did all it could; each new increase of power added some new moons to the number, until at last eight moons had been discovered. Then the camera was brought into use, and the two new, very faint and little moons were photographed from an observatory high up on the Andes mountains in the clear air of Peru. The first was found in 1898 and named Phœbe; the second in 1905 and named Themis.

These last little moons are so small that they could never have been discovered with the eye, even though aided with the greatest telescope now in existence. To find them is just the same as to find a small shot twenty miles away and to single it out from multitudes of other shot simply because of its motion, which in this case is so very slow as to amount to only half an inch each minute.

We have already explained why the camera will reveal heavenly objects to us when they are much too faint to be seen with the eye in any telescope. It is because the longer a camera looks the more it sees, for, as we have seen, the image of the star on the delicate photographic plate keeps on doing its work as long as it is there. In two hours it has done twice as much as in one, and so the longer the exposure is the greater will be the number of faint stars that will appear on the plate.

WHAT WE SEE ON SATURN WITH A TELESCOPE.

If we look at Saturn with a large telescope we see clearly a round, rather flattened, greenish colored ball, which has delicate bands or belts upon it similar to the beautifully colored belts of Jupiter, but very much less distinct. All of the faint bands encircle the ball of the planet parallel to the equator, so that from these alone we might strongly suspect that this great world is turning around very rapidly, even if there were no other ways of finding this out. For a very rapidly turning world would arrange the great hot mass of gas in layers, or belts, of just this kind.

Sometimes large, whitish areas are seen on the planet and sometimes there are other dim and irregular markings, and when we carefully watch these we can clearly see that the great world is turning rapidly around. But there is one very peculiar thing about its turning. When we study markings that are on the equator of Saturn we find that this part of the great gaseous ball is spinning around in the wonderfully short time of ten hours and fourteen minutes, but spots which are in higher latitudes require twenty-five minutes more to journey around the axis about which the whole mass is turning. The equatorial parts of the planet turn around most quickly; each day is there twenty-five minutes shorter than the day is in higher latitudes. The great mass of gas at the equator pushes ahead of the more slowly moving regions north or south of the equator with a speed of more than eight hundred miles an hour.

If Saturn were solid as our earth is, this peculiar way of turning around would tear the world all to pieces. It would be as if the northern halves of Africa and South America were to begin to move eastward, away from North America and Europe, at the rate of eight hundred miles in each hour, that is, so fast that they would have made a complete journey around the earth in one day and six hours. But Saturn, like Jupiter and the Sun, is still vaporized by its great heat; long ages must pass before the ringed planet becomes solid. And just as Saturn turns around more quickly at its equator, so do Jupiter and the sun also; the strange motion has been produced during the shrinking together of the greatly extended nebulas from which these worlds have been formed.

The equatorial regions of Saturn are usually the brightest, while the bands in higher latitudes are dark grayish or greenish zones. The polar regions are always darker than any other parts of the planet. But all these markings are faint and hard to see well. If Saturn were not so very far away we could doubtless detect a wealth of detail on its changing surface which would make it a no less interesting planet to study than the nearer Jupiter.

THE RINGS OF SATURN, AND HOW THEY WERE DISCOVERED.

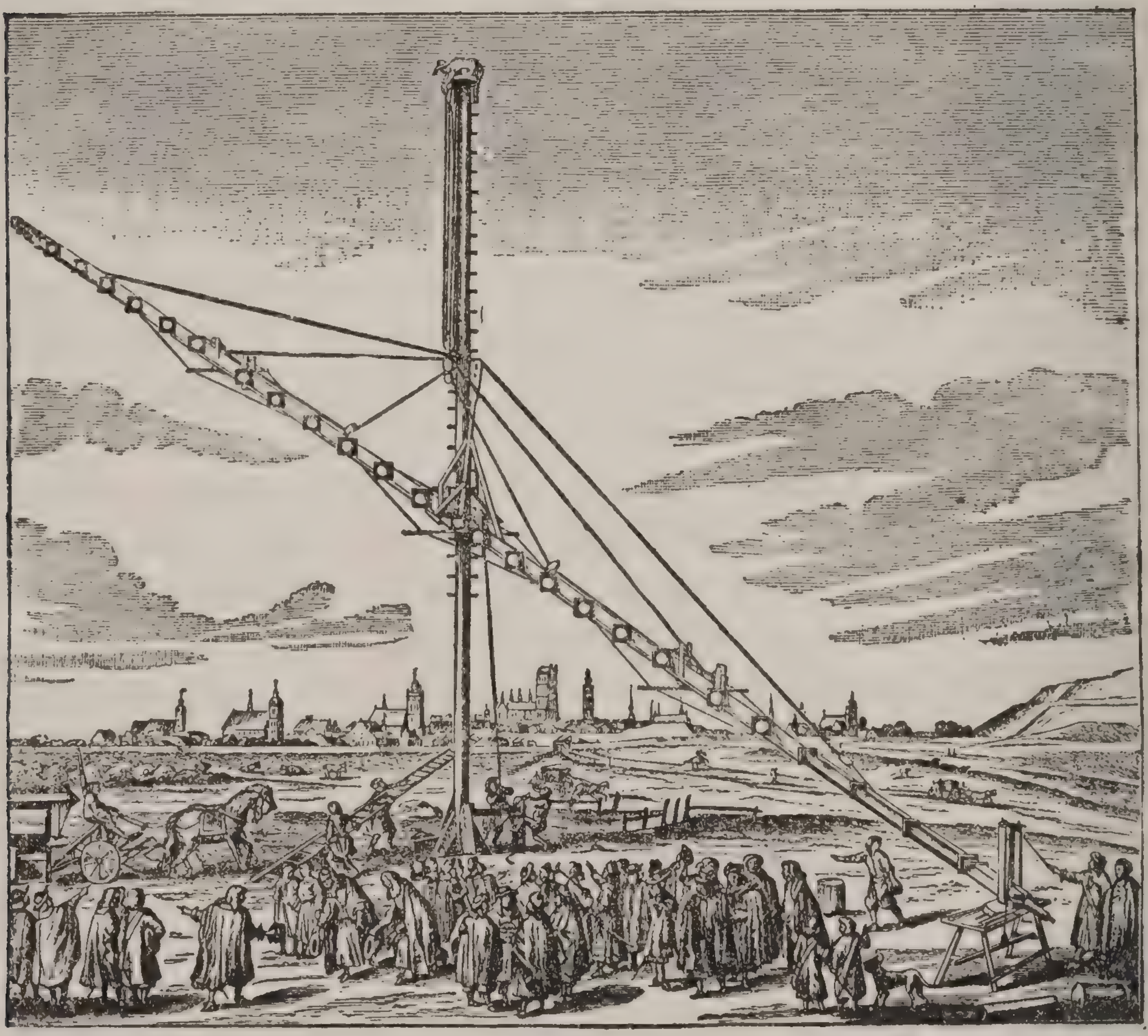
The most interesting thing about Saturn and its distinguishing feature is its wonderful system of rings. In a small telescope we see that around the central ball of the planet there is a strange, bright, flat ring, and this in a powerful instrument is seen to be made up of three rings, one within the other. It is these rings and also the ever changing moons that make Saturn one of the most beautiful and interesting objects in the sky. Its appearance as viewed through a large telescope, with the beautiful ellipses of the rings and the circle of the planet, glowing bright on a background of intense darkness, is a sight that once seen is never forgotten. No one enjoys it for the first time without an exclamation of wonder and delight.

The appearance of the rings as we see them from the earth is constantly changing. For they do not always lie edgewise toward us, but they are inclined, or tilted up, from our earth, and because they keep always tilted in just the same direction as the planet moves around the sun, it follows that during one half of their journey around us we look on their upper side and during the other half on their lower. On the two occasions when the earth is passing from the one side to the other we see the rings exactly edgewise. This happened the last time in 1907, and will again occur in 1922. At these times the rings, if visible at all, are seen only in the largest telescopes, and then they appear as nothing more than a mere line of light. They have been described at such times as looking like a knitting needle thrust through a ball of white yarn. The extreme narrowness of this line shows us that the rings are flat and exceedingly thin. A model of them six inches across would be no thicker than the paper of this book.

The rings seem to us to disappear in this way twice during every time that Saturn is passing once around the sun. As Saturn moves around its great path once in every twenty-nine and one-half years, we see the rings edgewise at an interval of fourteen and three-quarters years. In connection with the first time they were observed there is quite an interesting story which shows how because of their disappearance a famous astronomer just missed the honor of discovering them, and how nearly a half century passed before another astronomer could with extreme caution tell the world what they were. The first astronomer was Galileo and the second a young astronomer of Holland named Huyghens.

Galileo had just made his first little telescope and was examining the moon, the sun, Venus, and in fact anything that could be looked at in the sky. When he turned his glass on Saturn he was astonished to see there something entirely different from anything else he had found. In his small and imperfect telescope it looked to him like a vase with two handles on its sides; he described it as a large planet with two smaller attendants. In the course of only a few years Saturn had moved on in its path to the point where the rings turn their edges to the earth. Galileo looked at it again and to his utter amazement found that the two attendants were gone. ''Has Saturn devoured his children, according to the legend,'' he exclaimed, and he began to wonder if perhaps, after all, his wonderful ''optic tube'' was always right—if after all it did not sometimes deceive him. Filled with deep discouragement, he took no further notice of the Ringed Planet, and died without knowing that there was any ring there. Yet it would have needed only a little more patience and ingenuity to have found the true explanation; patience to wait until Saturn had passed the point of its path at which the rings are turned edgewise to us, and ingenuity to make a telescope which should show more plainly this wonderful appendage.

Astronomical discoveries proceeded slowly in those days. The wonderful discoveries of Galileo were looked upon merely as curious sights without any meaning at all. And so nearly fifty years went by before the young astronomer Huyghens, ambitious to learn something about the heavens, had made himself one of the largest and best telescopes then in existence; and this was the telescope with which the structure of the strange rings was for the first time to be seen.



The Telescope that Hevelius erected near the City of Danzic.

These seventeenth-century telescopes were curious affairs. We have a picture of one erected by the astronomer Hevelius on the common outside of the city of Danzic. It had no tube, but the two lenses were fastened at the opposite ends of a pole one hundred feet or more in length which was braced and stiffened by iron rods. A tall mast was fixed in the ground and by this the long pole was supported by means of ropes attached to its middle; it was raised and lowered by a windlass and pulleys. Anyone who has tried to work with even a small telescope can imagine what it must have meant to keep this very awkward and inconvenient glass pointed constantly on a moving planet, on a cold night, out in the wind-swept fields of Danzic. And we must have only the profoundest admiration for the infinite patience of the men who worked long and successfully with such crude telescopes and made with them so many splendid discoveries.

The length of the telescope of Huyghens was twenty-three feet, but the glass in its upper end was only about two inches across—a very little instrument indeed when compared with our giant telescopes of today. With this he was not long in finding out how the curious appearance of Saturn which had so mystified Galileo was a ring surrounding the planet, just as we now know it to be. He wrote the following sentence about Saturn in Latin, which then the language used by educated people in all the different countries of Europe: ''It is surrounded by a thin ring, not adhering to the body at any point, and inclined to the ecliptic.'' But instead of sending this sentence written out in this way to other astronomers so that they could understand it, he only sent them the letters of the sentence all mixed together, just as one mixes up the letters of a word in a game of anagrams. He did this to prevent any other astronomer from claiming the honor of the discovery. The other astronomers could make nothing out of this very long anagram, and so after he had had time to look more carefully and to be sure that he was right beyond any chance of a mistake, (which would have ruined his reputation as a careful observer), he told them how to place the letters in their proper places and so to learn of the discovery he had made.

The astronomers who followed Huyghens with better and stronger telescopes added each his own contribution to the knowledge of the rings: about twenty years later Cassini found that there is one ring within another, and so the narrow space between them has been called Cassini's Division. And in 1850, W. C. Bond, of the United States, discovered that there is a third ring within the other two—a very pale and transparent ring which is very much harder to see than either of the two others. On account of its great faintness this is called the Dusky ring.

WHAT THE RINGS OF SATURN ARE MADE OF.

From the time of their first discovery, a question that most perplexed astronomers was, What are these strange rings—what are they made of—what are they like? The great astronomer Laplace first proved that they could not possibly be one solid piece, or arch, because no material there is could be strong enough to withstand the changing pulls which would be ever bending and disturbing it. Even the strongest steel would be torn to fragments by the strains which such rings would have to endure, not only from the pull of Saturn, but also from that of the outside moons and from the internal strain of its own motion. Next it was proved that the rings could neither be made out of a liquid or of a gas, for if they were, great waves would be set up in them which would slowly destroy their form. And so it followed that they must certainly consist of a great swarm of solid particles, in no way connected with one another, each one of which is revolving around the planet in its own path as independently as if it was the only one there. The astronomers had therefore proved that what look to us like solid rings are nothing but an immense swarm of millions of little moons, moving around Saturn. It is only because there are so very many of them and because they are so close together that they look to us like a solid ring.

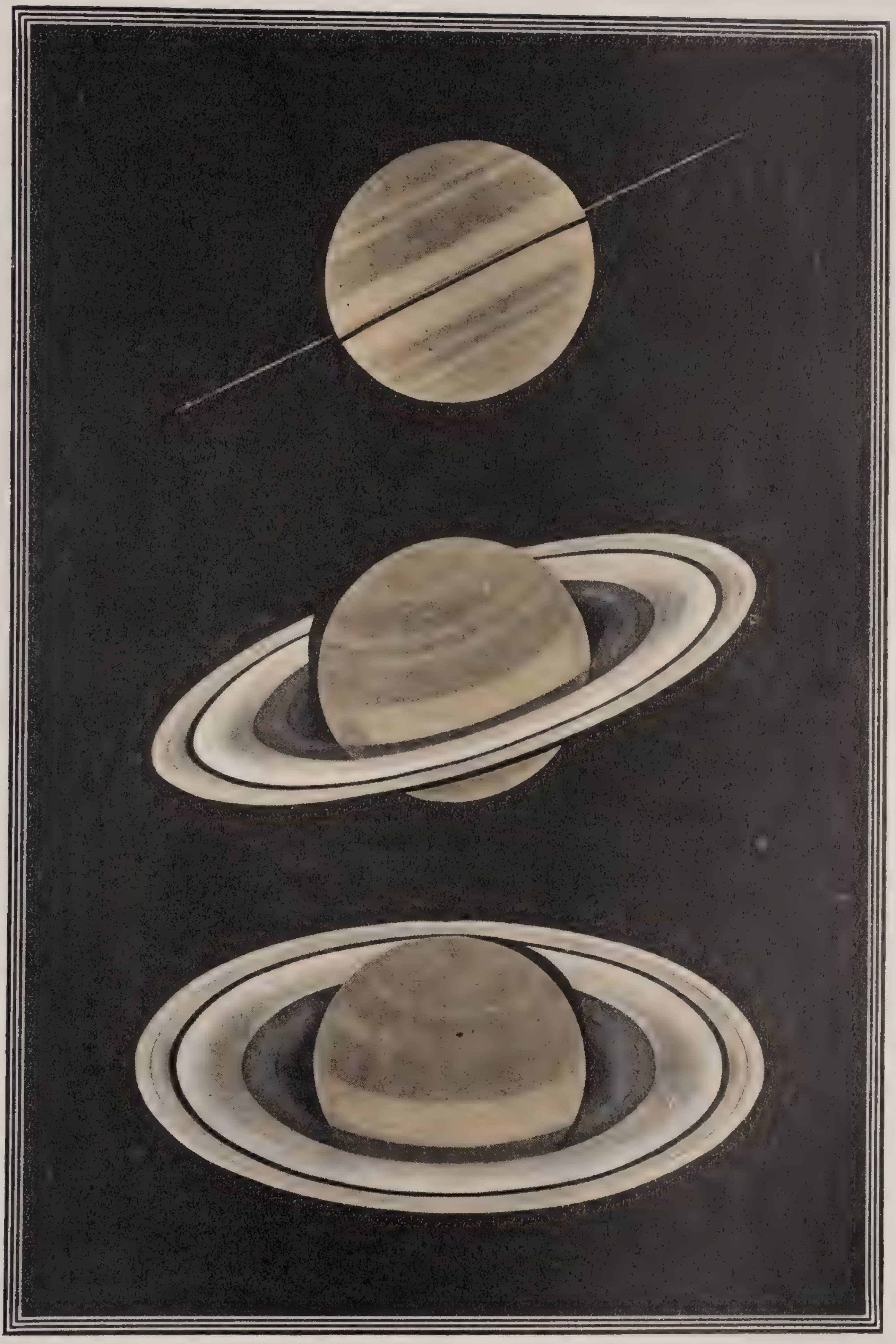
Many years after this had been proved mathematically, men learned how to show to the eye by the spectroscope that each separate little piece of the rings is moving independently of every other piece. The work of showing this was a most delicate and difficult piece of manipulation. It meant keeping a minute image of Saturn focussed for hours exactly upon the very narrow slit of the spectroscope while all the time a photograph was being taken of the little pale spectrum, or color strip. This little color strip was crossed by many black lines, just as we have learned that the color strips of the sun and the stars are. And by studying the positions of these little black lines we can find just how rapidly each little part of the rings or of the ball is moving toward or away from us, just as we can find with the spectroscope whether we are drawing nearer or farther away from a star. When the little photograph was put under a microscope and carefully measured it was found that both the ball and the rings of Saturn were rapidly turning, but it was seen that different portions of the rings moved at different rates of speed, the inner parts moving fastest and the outer ones less swiftly.

This is a state of things that can only exist if the rings are made up of a swarm of separate particles, and it is just what happens whenever many bodies are made to move around a greater, central ball by the pull of gravity. Thus we know that Mercury moves faster than Venus, that Venus moves faster than the Earth, and so on—the farther any planet is from the sun the more slowly it moves. And the spectroscope showed that in just the same way the farther any particle was from the ball of Saturn the more slowly it moved, and that each particle was moving just as fast as a separate moon would do if placed in that position and pulled upon by the gravity of the planet.

WHAT WOULD BE SEEN FROM THE SURFACE OF SATURN.

Interesting and striking as Saturn's rings are when viewed from the earth, their appearance to a dweller on the planet would be startling to a degree hard for us to imagine. Of course, we must remember that it would be quite impossible for any life to exist on Saturn; for the whole planet is so hot that it is in a state of vapor. But as we took an imaginary trip to Jupiter, we may also think of ourselves traveling to the more distant Saturn, and let us imagine that we first alight near the pole of this more than white hot planet. From here we would see nothing of the rings at all, but if we began to walk toward the equator we would find that when we had come so far as a latitude of seventy degrees, a strange, broad segment of light would begin to be seen just arching above the ground, far in the south. As we walked farther southward this would seem to rise farther and farther from the ground, and by the time we reached a latitude of forty degrees it would stretch across the southern sky a truly inspiring sight—a series of brilliant bows like immense white and shining rainbows, one within another, only ever so much broader and brighter.

We can scarce conceive the awe-inspiring effect of that gigantic series of bows. We are overpowered by its tremendous influence as it dominates the midnight sky. Held by its spell we forget the stars as they come and go, now retreating behind it; now suddenly appearing again. We see the shadow of the world on which we stand as a broad, black break in the smooth curve of the rings, and as we watch this shadow it sweeps up from the ground in the east and on toward the west like the hand of a gigantic clock of which the rings are the face, telling us of the passage of the night. And how swiftly it moves! In two and one-half hours it has reached the meridian, and in five it begins to sink in the west, and the eastern twilight, causing stars and rings to disappear, proclaims the



THE PLANET SATURN.—The first picture shows how the rings look when we view them edgewise; in the lowest picture they are seen as much widened out as they ever are. The black line across the ball in the first picture is the shadow cast by the ring; in the last two pictures the shadow of the ball on the ring may be seen.

beginning of another day. For we are now on a planet of which the day is only a little more than ten hours long.

Let us stay many of our years on the Ringed Planet, until its autumn passes and its winter draws near. Then we will find that the rings, once so glorious in the night, furnishing more moonlight than all the ten moons together, begin to be a great inconvenience to us. For the sun in the winter time is shining on the south side of them so that they are lying then between the sun and us. Instead of shining gloriously at night they show their presence only by the broad starless places they blot out in the sky. When the winter sun rises we will find that its tiny disc, no more than one-ninth as far across as the disc we see from our earth, will be completely hidden by the rings for a short time after sunrise and again for a time before sunset. Now begins a season of eclipses of the sun, longer or shorter, with brief intervening intervals of sunshine, that continues on through Saturn's winter and does not cease for nearly fifteen years. For winter on Saturn lasts nearly thirty times as long as it does with us. Sometimes the sun is not seen at all for many months. Sometimes it shines for only a short time in the morning and afternoon as we see it between the narrow line which is between the inner and outer ring. In mid-winter, after the beginning of the day, it would shine with a dim light through the semi-transparent, dusky ring. Very interesting at first would be this game of hide-and-seek which the sun would keep playing among the rings throughout the long winter, but after the novelty wore off we would find ourselves longing for the days of constant sunshine to come again, and think with regret of the pleasant earth we had left.

And so we would return to Mother Earth, more than ever appreciating our home—the best, the most beautiful and most interesting of all the planets. Here we enjoy the glory of an unobstructed expanse of sky, rejoice in broad and fertile plains giving us an abundance of food and in wide expanses of oceans which moderate the climate and protect us from the extremes of heat and cold. Here the light is neither too bright nor too dim and the days are neither too long nor too short. The size of our world is just right to give to our bodies and to everything else just the right weight, so that we are not unduly oppressed with our heaviness and yet are held firmly down to the solid ground. In short, on our own little world all things are the best possible and are exactly adapted to our varied needs.

CHAPTER XIV.

Uranus, Herschel's Planet.

AN ASTRONOMER WHO FOUND A NEW WORLD.

THE discovery of Uranus by William Herschel marks the first real enlargement of our knowledge of the Solar System. We might call it the first step of the human mind into the trackless wilderness which lay beyond the bound of what had been known from the first. Even Galileo and his successors, with all their brilliant discoveries, were, after all, only finding out more things about those heavenly bodies which men had already seen. Galileo with his little spy-glass, and Huyghens, Cassini, and others with their great spider-like telescopes had brought to light only additional facts about Venus, Jupiter, Saturn, and other heavenly bodies which from most ancient times had been named and talked about. There was no knowledge of what lay beyond. Not only was Saturn believed to be the outermost of all the planets, but the stars were thought to be only a very little way beyond this distant world. Men had no sort of conception of the real relation of things in space. Even the actual distances of the sun and planets from each other were not accurately known.

It can be said of Herschel, as it can be said of every great genius, that while he thought the thoughts of his fellow men, he thought them much more clearly. So while other men were vainly puzzling themselves and wondering about the structure and conformation of the heavens, he was thinking over the same riddle, but with a clearness of perception that found the way to solve it. He possessed a rare mechanical ingenuity that could construct the apparatus needed to find out, and a tenacity of purpose that would persevere until the way was cleared for others to follow.

The problem that Herschel proposed to himself was as daring in conception as his patience and perseverance were masterly in its execution. It was no less than to discover the structure and size of the universe of stars, and the industry of his long life, filled with an astonishing amount of work, shows the enthusiasm of his determination to solve it.

It might be said that Herschel started out to sound the depths of starry space, and that on the way he stumbled across and found a planet. It makes no difference that the discovery of Uranus was an accident and that the fame that he received for it is out of all proportion to the credit he deserved for other labors—vastly greater labors, which were given comparatively little consideration because they had in them so little of the sensational. The greatest discoveries have almost always been accidents—a sort of by-product of other work undertaken in the pursuit of some very different object. The glory is deserved rather for the industry and determination without which there would have been no "accident."

As we see him seated at his telescope on that memorable night of March 13, 1781, Herschel forms one of the most interesting figures the world at that time could show. His life had been spent as a musician, first in the army in Hanover, then amid more or less unsettled conditions in England, and now he is organist in the Octagon Chapel in Bath. All this time he had been filled with an unquenchable ambition to see in the heavens what had never been seen there before, and to know what had never been known. He was too poor to buy a telescope, so he had made himself one. Rather, he had made many—great, small, and middle sized—and selecting always the best, used it for exploring the stars. These telescopes were all reflectors; that is, instead of looking up at a star through a tube with a glass in the upper end he would look down into the tube away from the star and see its reflection in a concave mirror at the lower end of the tube.

A Great Reflecting Telescope.

The work of casting, grinding, and polishing these mirrors passes all conception. After a day's hard work of teaching music, and an evening spent in directing an orchestra, he would hurry to his shop and become so absorbed in his work that he forgot the passing of time or his own weariness till the night was gone. His sister Caroline, who herself became a famous astronomer, would sit by him, reading to him from the *Arabian Nights, Don Quixote,* or some other book, to beguile the time. At times his interest in completing a mirror became so intense that he would forget to eat; we are told that he sat at his work sixteen hours without leaving it and his sister put the food, which he otherwise would have left untasted, into his mouth.

When the instrument was finished he would sit many a time all night under the open sky with the thermometer down near zero. Frost and ice would collect upon his telescope; the lenses get dim with moisture and require constant wiping, and at times he would find his feet frozen to the ground when the morning twilight dimmed the stars and warned him that it was time to cease his work. And so, night after night and year after year, he went on, discovering new things, writing about them, amassing a vast amount of knowledge about the heavenly bodies, and what is even more, showing the way to work and inspiring others with a new enthusiasm to take up the work themselves and pursue it by similar methods and with a new perseverance. And thus William Herschel gained the name that has justly been conferred upon him of the "Father of Modern Astronomy."

HOW THE NEW WORLD WAS DISCOVERED AND WHAT MEN AT FIRST THOUGHT IT WAS.

Such was the man who on the night of March 13, 1781, we find at his telescope, "rummaging among the stars," who before midnight arrived had added another planet to the solar system and advanced the borders of our sun-family no less than nine hundred millions of miles. There was nothing whatever that was sensational about the discovery however. It is but a simple story. As the stars swept through the field of his telescope he examined each one to see if there was anything unusual about its appearance. Suddenly he stopped, for he noted one star that seemed different from the rest. Instead of seeming to be a mere point of shining light, it was pale and had a round disc which shone with a sort of greenish color. Then followed an hour or more of patient watching in the course of which time he detected that the new body was slowly moving among the stars.

But Herschel was at first utterly unconscious of the nature of the object which was destined to bring him an undying fame. He entered upon his notebook the following singular record—"The sequel has shown that my surmises were well founded, this proving to be the *comet* we have lately observed.'' Such was the character of the report he sent at once to the world of astronomers, where a most profound sensation was produced. It led eventually to no small controversy, and many, clinging to Herschel's suggestion, thought that the new body was a comet. But when on watching its motion and computing its path it was found to be moving in an almost exact circle, nearly two billions of miles from the sun, it became certain that this could not be so. For no comets had ever been found which moved in such a path. And when the astronomer Bode, computing backward, found that it had been observed twenty-five years previously and recorded as a star, and when another astronomer by his calculations showed the form of its path and the distance and probable period of this new body, it was finally proved indeed to be a great, new world.

It may seem strange that so long a time should have passed before this wonderful discovery was admitted, and almost as if the astronomers did not wish to believe that Herschel had really discovered a new world. But this is not so. All were eagerly hoping that their suspicions might be definitely confirmed and proved, but astronomers are exceedingly accurate and cautious and will not express an opinion until the certainty of their conclusions has been most thoroughly tested. Thus when the eighth satellite of Jupiter was seen in 1907, it existed for a long time in the minds of astronomers as ''possibly an asteroid,'' until at last its real nature as a new moon was proved beyond a doubt.

NAMING A PLANET.

The next question that arose was what name to give the new planet. When its discoverer was looked to, he, patriotic Englishman as he was and grateful to his king, said ''George's Star,'' (Georgium Sidus). But while the scientific world were silent as to their opinions of this king's lack of all desert to such an immortality, they quietly dropped the name suggested by Herschel. The suggestion of Lalande, the French astronomer, that it be called ''Herschel,'' though made with more reason, eventually met the same fate. And so it came to pass that to Bode came the honor of naming the new planet ''Uranus.'' There is an appropriateness in this name, for neither George III nor Herschel would have been at home in the company of Greek gods whose names have from time immemorial distinguished the planets.

The discovery of Uranus created the greatest excitement in the world, not only among astronomers, but outside the astronomical world as well. The discoverer was knighted and thus became Sir William Herschel. He was also appointed Royal Astronomer, given a pension, and provided with funds for constructing a giant telescope, greater than any that had thus far been made. With this great, new telescope, new discoveries of the highest importance were afterward made. But the man who had thus in a night leaped from obscurity into the highest fame, remained still the modest, gentle, benevolent spirit that he was in the days of his deepest poverty; playing his violin for a friend with all good nature, or showing the heavens in his telescope to increasing crowds of lords and ladies, as well as to the common people that assembled on his lawn. He continued to patiently grind away at new reflectors, and still more patiently to watch the silent stars go by as he reviewed them with the keen eye of his telescope. For neither royal honors nor popular applause could divert his heart from the sublime science to which he had vowed eternal fidelity.

HOW URANUS LOOKS IN A TELESCOPE, AND WHAT ASTRONOMERS HAVE FOUND OUT ABOUT IT.

What is actually known about Uranus is not very much. Its vast distance from the sun and the consequent dimness of its illumination, and also its great distance from us, combine to make it a very difficult object in the telescope. It takes a large instrument to show it at all to any advantage, and then it is only a very small, pale, greenish disc, with no markings except such as lie at the very limits of seeing.

In size Uranus is a little less than one-half as large as Saturn, the distance through it being thirty-two thousand miles. About six years after it had first been seen, Herschel discovered that it had two moons, and he thought that he had found four more. Nothing has since been seen of these four, however, and they were doubtless illusions. In 1851, the astronomer Lexell discovered two other exceedingly faint little attendants, nearer the planet than Herschel's two. Calculating from the amount of work which Uranus must do to keep its moons in their paths and prevent them from wandering off into space, astronomers have been able to find its weight very exactly. Knowing this and also its size, it is easily discovered that Uranus is a very light planet, probably so expanded by its immense heat that, like Jupiter and Saturn, there is nothing solid about it. Yet it is possible that there may be a small core of solid matter near the center, but which is surrounded by a very deep blanket of hot clouds and gasses. It has been thought at times that belts like those of Jupiter have been dimly seen on Uranus, but this is very uncertain.

The four moons of Uranus move in paths which are strangely tilted up to the earth's path. Indeed, instead of looking at these paths nearly edgewise, we look almost perpendicularly upon them and see them in nearly their true shape, as round, almost perfect circles. But even more strange than this is the way in which the little moons move along these paths. For they move backward from east to west instead of from west to east as our moon does. The largest of these little moons is about one thousand miles through and the smallest about four hundred miles. They are named Ariel, Umbriel, Titania, and Oberon.

The distance of Uranus from the sun is nearly eighteen hundred millions of miles and its year is eighty-four times as long as ours. The length of its day is uncertain because the absence of any markings on the planet has thus far made it impossible for us to find out certainly just how long it takes it to turn around. It is thought that probably it turns rapidly, just as Saturn and Jupiter do. Uranus is so very far away that this world receives hardly one four-hundredth part as much light and heat from the sun as we do. To one who stood on this world the sun would look almost exactly as bright as an electric arc lamp would do if it were placed fifteen feet away. This sunlight would be considerably brighter than our brightest moonlight, but yet very faint indeed when compared with the glory of a day with us.

Uranus is so far away that it can barely be seen with the naked eye. On unusually favorable occasions, when the air is clear and the planet is not too near any bright star in the sky, it has been seen as a faint star just within the limits of vision. It can be viewed with an opera glass or small telescope, but it then shows only as a faint star, and it is only by watching it from night to night in order to detect its motion among the stars that we can recognize that it is a distant, moving world.

CHAPTER XV.

Neptune, the Planet Farthest Away.

HOW THE EARTH PULLS EVERYTHING TOWARD ITSELF.

EVEN when we were very young and first began to notice things around us we learned that everything tends to fall to the earth. Every movement of our body tells us this. If our foot slips or if we stumble we are in danger of falling; if we are sleepy our head nods, and we lie "down" to rest comfortably. The rain falls and runs into the brooks and then into the rivers and the sea, always trying to get nearer to the center of the earth. Birds fall when shot, and aeroplanes fall to the earth if their motors fail to work. So we see that everything on the earth always tends to fall to the earth; the earth is pulling everything toward itself. It is only another way of saying this same thing to say that everything has "weight." This pull of the earth which we feel as weight is called the *Force of Gravity.*

We are so familiar with the strange force of gravity that we take it as a matter of course and give little thought to the reasons for it. After much study men are still unable to tell anything about how or why one body may pull another. We know how gravity acts, and how strong it is, but how one body can pull another, as the earth pulls everything toward itself, is still a mystery.

What boy has not played with a magnet? It is a delight to him to see it pick up pieces of iron and steel. And he soon finds that the heavier the piece of steel is the shorter will be the distance it will jump; the pull of the magnet is not strong enough to make it jump farther. If the steel is brought against the magnet, the two will cling together so tightly that the steel may be lifted up by the magnet if it is not too heavy. The boy also knows that if he has a stronger magnet, usually a larger one, he can make the pieces of steel jump longer distances and that he can pick up heavier pieces. It is thus clear that the pull of a magnet is not the same at different distances, but that it grows weaker rapidly when the steel is moved farther and farther away. It also shows that some magnets can pull much harder than others. This simple plaything illustrates clearly the great law of gravitation.

The earth pulls like a great magnet, except that it pulls everything toward itself and not only things made out of iron and steel. Its pull grows weaker when the body being pulled is moved farther away, just as we saw that the pull of the magnet did, but it is much more difficult to show that this is so with the earth than it was with the magnet. This is because it is the center of the earth that is the center of the pull and not the earth's surface, and we are only able to change the distance of a body from the center of the earth a very little part of the whole distance. But it is found by careful observation that as we move away from the center the pull of the earth does really become less, that is that bodies weigh less at the top of a high mountain than they do in the valley below. When Peary was at the North Pole he was thirteen miles nearer the earth's center than he would have been at the equator. For this reason the earth's pull on him was greater. If he weighed one hundred and forty pounds at the equator he weighed one-quarter of a pound more at the Pole. When it is necessary to be very precise in weighing we must tell where on the earth the weighing was done.

THE DISCOVERY OF A GREAT LAW.

In the year 1686 Sir Isaac Newton published the greatest discovery that any man has ever made or is ever likely to make. He found that the pull of the earth is but one evidence of a great law which is known as the Law of Universal Gravitation. He discovered that every little particle of matter in the universe is pulling on every other little particle, and he showed that we can always find exactly how strong this pull will be. He showed that to find this pull we must multiply the amount of matter in one body by that in the other, and then multiply the distance between them by itself, and finally divide the first product by the second. This will give us the pull between the two bodies. If with one pair of bodies we found a quotient ten times as large as with another pair, then we would know that the bodies of the first pair pulled each other together just ten times as strongly as those of the second pair.

From this law we learn that every object, large or small, attracts every other object. The earth pulls down on your body and your body pulls up on the earth. A book attracts the table upon which it rests, the table attracts the book, and the earth pulls on both of them. The attraction between small objects is exceedingly minute but nevertheless we know that it exists. Exceedingly delicate experiments have been made in which the pull of two small gold or lead balls on one another can be seen and measured. The great importance of the wonderful law, however, lies in the fact that by it we can explain all of the complicated motions of the heavenly bodies.

Suppose we tie a stone to a string and whirl it around and around in a circle. Why does the stone not drop to the ground when there seems to be nothing to keep it from falling? It is because the whirling makes the stone try to get as far from the center of the circle as it can, and this force is stronger than gravity. If some one should suddenly stop the stone by placing a piece of board in front of it it would at once fall. If the stone were whirled so rapidly that the string broke it would fly off to a great distance and finally fall to the earth. But if there were no air and if the earth did not attract the stone it would move on forever in a straight line, for we know that it requires a force of some kind to stop it or to change the direction of its motion.

Now the moon is moving in such a circle about the center of the earth, and there must therefore be some force which is pulling the moon toward this center. There is nothing like the string to keep it from flying off, as there was with the stone, but it is clear that there must be something which acts like the string and keeps the moon in its path. Newton found that it was the pull of the earth which keeps the moon from flying away, and that the force caused by the whirling around of the moon keeps it from falling onto the earth. The two forces are exactly balanced. If it were not for the attraction, the moon would leave us, flying off in a straight line; the attraction makes it move toward the earth and out of the path it would otherwise follow. Thus, although the moon is always at the same distance from us, it is in a sense always falling toward us. The moon like any other object falls toward the earth, for it is nearer to the earth each instant than it would have been if gravitation had ceased to act the instant before.

In just the same way that the pull of the earth keeps the moon forever moving around it, so the attraction of the sun keeps each of the planets in their paths, and they in turn keep their own moons always revolving around them.

HOW STRONGLY THE SUN PULLS THE EARTH.

It is the sun's attraction for the earth which keeps our world always moving around its path. If this pull should ever cease the earth would go flying off into space in a straight line just as fast as it is now moving; that is, it would fly away with a speed of eighteen and one-half miles a second. If the earth could be suddenly stopped in its path, it would at once begin to fall toward the sun. It would move very slowly at first; during the first second it would only fall one-ninth of an inch, but its velocity would rapidly increase and it would at last strike the sun with the enormous speed of three hundred and eighty miles a second. Nevertheless it would require two full months for the earth to fall into the sun.

As the earth is so very far away from the sun it may be thought that the sun's attraction for it is very small. From the great law of gravity we know that if the earth and the sun were so close together that they touched each other, the attraction between them would be forty-five thousand times as great as it now is. But even though the earth is so far away the attraction is by no means small. To keep the earth in its round path, if there were no attraction, we would have to tie it to the sun with a rod of the very best steel three thousand miles through. This is a rod one-seventh as far through as the distance through the whole earth itself. This shows us how enormous the force is, for a rod only one inch through will support a weight of about a hundred tons.

If we prefer to bind the earth to the sun with a great many heavy telegraph wires, we would need to have ten wires fastened to every square inch all over the whole half of the earth which is turned toward the sun. The attraction between the earth and the moon is one one-hundred and seventy-fifth part as strong as that which acts between the earth and the sun. How such stupendous forces can act across space from one body to another is an unsolved mystery.

HOW ALL OF THE WORLDS ARE PULLING ON EACH OTHER.

If its motion were caused by the pull of the sun alone, each planet would move in a perfect ellipse. But from the law of gravitation we know that each of the other planets, and every other body no matter how small, are always pulling on it too. The other planets are so much smaller than the sun that their pulls are much less strong than the sun's pull, but yet in working out just how any world will move none of these little pulls can be neglected. They make the planet move in a very irregular path, but yet it is never very far away from the path in which it would move if the sun alone pulled it. Astronomers can find just how strong the pulls of every planet are and what changes they will make in the path of any other planet. Thus Newton and those who lived after him had explained by the law of gravitation nearly all of the complicated motions of the bodies of the solar system, and were able to tell just where any world would be at any time. But the planet Uranus puzzled astronomers greatly, because it would not exactly follow the path they had found for it. They searched carefully for mistakes in their long computations, but still could not discover the trouble. As the law of gravitation had explained the motions of all the other planets so well, they were nearly sure that this law was true. Yet it was clear that either the law was wrong or else that there was something always pulling Uranus which they did not know about. Some suggested that perhaps there was an unknown world far out in space, and that it was the pull of this world which was disturbing Uranus in its path.

HOW THE LAW OF GRAVITATION TOLD ASTRONOMERS OF A GREAT UNSEEN WORLD.

Even when we know how large a planet is and just where it is, it is a very long and difficult work to find exactly how its pull will disturb the motions of all the other planets. But the motion of Uranus made a far more difficult problem and one which many astronomers thought could not be solved. From the little pull which seemed to be ever disturbing the motion of

Uranus would it be possible to surely find all about the position and size of the unseen world from which the little pull came?

Difficult as the problem was, two young men were bold enough to try to solve it. One of the young men was a Frenchman named Le Verrier and the other was an Englishman named Adams. After two or three years of tedious and most difficult work each succeeded gloriously in solving the problem. Their results were reached in the year 1846 at almost exactly the same time and agreed with each other very closely. They told astronomers who had great telescopes to point them at a certain place in the sky, and there they would find a planet that man had never seen before. This was the distant world which by its little pull had sent the message to us that it was there, far out in space. The astronomers found the planet, just as they had been told that they would. The first man who ever saw the new world with a telescope was a German astronomer named Galle; this astronomer died in 1910 at the age of 98 years.

The discovery of a planet in this wonderful way aroused the greatest enthusiasm. It was a triumph of the great law of Newton and a striking tribute to the power of the human mind; nothing could have shown more clearly how thoroughly astronomers understand their science. So remarkable a discovery gave people great confidence in the laws of astronomy, for prophecy fulfilled is the best evidence of the truth of scientific laws. The new world was found to be a round body of a greenish color, and was named Neptune, the God of the Sea.

It is interesting to know just how far Uranus was pulled out of its path by the action of this new world. If you will look at the group of stars called the "Big Dipper," you will find that the star next to the end of the handle has a little star quite close to it. Now the whole change in the place of Uranus which astronomers were trying to explain was only one-sixth part as much as the distance between these two stars. If two stars were separated by a distance equal to this they would look exactly like one star to our eye. It was only so very small a disturbance of Uranus as this which worried astronomers and led to the discovery of the new planet Neptune. And the new world was found less than five times the distance between these stars away from its predicted place, a marvellous accuracy when we think of the difficulty of the problem.

Why had not astronomers seen Neptune before? It was in fact found that in searching the heavens they had actually seen it many times. But Neptune is so far away that in any except the very largest telescopes it looks almost exactly like a small, greenish star. No one ever noticed that this particular star was moving slowly, which showed that it was not really a star at all. As the planet does not look like a round world in small telescopes it could only have been found to be a planet by its motion. There was one astronomer who measured its position several times, fifty years before it was discovered, but each time he thought that the faint, greenish light was nothing but one of the thousands of distant stars which are in the heavens.

A WORLD ABOUT WHICH WE KNOW LITTLE.

Neptune can not be seen at all with the naked eye: in a small telescope or pair of opera glasses it looks like a faint, greenish star. The planet looks so faint because it is so far away from the sun and from us, and not because it is really small. It is a great world eighty-five times larger than our own earth. It is the farthest planet from the sun so far as we know. It is half as far away again as Uranus, three times as far away as Saturn (which is the most distant planet usually visible to the naked eye), and thirty times as far away from the sun as our earth.

As the distance to Neptune is so very great it is difficult to make a correct map of the solar system. We find in almanacs and geography books many maps which give the order of the planets correctly but which give a wrong idea of their distances. On a map four inches wide the orbit of the earth should only be one-eighth of an inch across, and the orbits of Mercury and Venus should be still smaller. If the earth's orbit were drawn as large as a quarter-dollar then the orbit of Neptune should be as large as a bicycle wheel.

We cannot conceive of the distance to the sun and much less can we understand the distance to Neptune. It is two billion eight hundred million miles away from the sun. If Adam could have started to Neptune, traveling day and night without rest so fast as a mile a minute, he would just about be arriving at this distant planet now. Even though light travels one hundred and eighty-six thousand miles each second it requires four and a quarter hours to come from Neptune to us.

We know less about Neptune than about any of the other planets because it is so far away that we cannot see it so well as we can see the other worlds. In the telescope it has a small round disc of a greenish color. Sometimes we can see dim bands around it but we can see no other markings on it: we therefore cannot tell whether it turns around upon an axis like the other planets, but it probably does. We cannot see any canals, or belts, or rings such as make the other planets so interesting. It has one moon which is believed to be about as large as our own moon. Perhaps there are other moons there which we cannot see because they are too small or too close to the planet.

Neptune is eighty-five times as large as the earth but it is only seventeen times as heavy. It is in fact only a little heavier than water and from this we are sure that the planet is still very hot, as all of the outer planets are.

WHAT WE WOULD SEE FROM NEPTUNE.

If we were on Neptune the sun would not look round to us, but it would shine out in the sky only as a very bright star. It would only send us one nine-hundredth part as much light and heat as it sends to our earth. Even mid-day would seem indeed dim and dark to us, and yet the feeble sunlight would be seven hundred times as strong as the light which we receive on the earth from our full moon. If the planet were kept warm by the sun alone it would be intensely cold there.

On Neptune we could not see the earth at all or in fact any one of the four earth-like planets. We would see Neptune's one moon moving about the planet in a little less than six days. In following its path among the stars it would journey around the sky from east to west instead of from west to east as our moon does.

Neptune is so far away from the sun that it does not need to move very fast around its orbit to balance the sun's attraction. In fact it moves only 3.4 miles a second; the earth moves five and one-half times as fast as this. Neptune requires one hundred and sixty-five years to make one circuit of its mighty orbit. From this we know that Neptune's years and seasons are one hundred and sixty-five times as long as ours. Few of us would live to be half a year old on Neptune. If we were born in the spring we would die of old age before the next winter.

CHAPTER XVI.

Other Bodies which Move Around the Sun.

HOW THERE IS A STREAM OF MANY HUNDRED LITTLE WORLDS MOVING AROUND OUR SUN.

OUTSIDE of the path of Mars, but nearer to the sun than Jupiter, there are hundreds of worlds which are the strangest little bodies imaginable. The very largest of them all has less land on it than the country of Mexico, and if we could lift up a mountain and carry it so far away from our earth that it would begin to move around the sun, it would become a world as large as the smallest of the little worlds which are really there. All of these little bodies are called Asteroids, and each one has its day and night, and moves around the sun just as the large worlds do.

All of the asteroids are so far away that they look very small, even in the largest telescopes. We can see that the larger ones are round worlds and we can measure how large they are but the smaller ones look just like points of light and we cannot even tell whether they are round or not. Many astronomers think that these smaller worlds are like great, uneven rocks about ten miles through and that they are of all sorts of shapes, just as stones on the earth are. All asteroids are dark, cold bodies, and we only see them because the sun is shining on them; sometimes the smaller ones look brighter than at other times, and this may be because they are not round so that they sometimes turn their largest sides toward the sun and toward us and sometimes their smaller sides. When only a little of their surface is turned toward us they look very faint, but when we see their larger sides they look much brighter. Still, we do not know that this is so. They may all really be round, but covered with very dark and very bright spots, and when they look brightest it may only be because we are then looking at the part of them which is really brighter than the rest.

The first of all these little worlds to be found was named Ceres, and this is the largest of them all. A great astronomer named Piazzi, who lived in the island of Sicily, had for a long time been very carefully measuring the exact positions of very many stars on the sky, when he found one night that one of them seemed to be moving. We know that all of the stars are so very far away that even though some of them are rushing through space many hundreds of miles a second we can not see that they have really moved unless we watch them for a long time. So this astronomer knew that the little body he saw was not really a star, but that it must be a world near our sun, which he was the first man ever to discover. He found the new world on the first of January, 1801, and it must have given him more pleasure than any other New Year's present could possibly have done.

For more than a month he carefully measured its path as it moved over the sky among the stars, and then he fell dangerously sick. The letters which he had sent out telling what he had found were carried very slowly in those early days, and before any other astronomers heard about it the new world had drawn so near the sun that it could no longer be seen. But a celebrated student of mathematics named Gauss found out for the first time during the next summer how we can tell exactly where such a little body will be found among the stars and what its path will be for very many years in the future, even if it has only been seen three times before. He told astronomers exactly where they should look to find the lost little planet when it next drew away from the sun, and on December 31, almost a year after it was discovered, they looked, and there they found it, moving along in its path just as Gauss had said that it would do.

A WORLD FROM WHICH WE COULD JUMP AWAY INTO SPACE.

If we could go to the little world Ceres, what would we find? A world so small that it is only four hundred and eighty-five miles through,—so small that the distance all the way around it is only as much as the distance from New York to Kansas. There is very probably no water and no air there, but if we could stand at the edge of a Ceres sea, or on a level plain, we would see the little round world bending downward so much that we could not look a mile away in any direction. If a man began to walk away from us, his feet would begin to disappear behind the curving ground, and as he kept on walking we would see his body seem to sink farther and farther into the earth. When he was a mile away all that we would see of him would be his head seeming to come right out of the ground; all the rest of the man would be hidden behind the round ball of the little planet.

Ceres is so very small a world that it could not pull downward on us very hard. A boy who weighs one hundred pounds here would weigh less than six pounds there; if he could jump three feet high on the earth he could jump fifty feet high on Ceres. He could easily spring over a high house, and when he came down on the other side he would fall so slowly that he would not strike the ground any harder than he would do if he jumped from a table to the floor on the earth. He could throw a base ball or a stone half a mile high, and after he had thrown the ball up it would be eight minutes before it fell to the ground again. All of this is because on any world our weight and the weight of all bodies is caused by the downward pull of the world upon them. Ceres is so much smaller than our earth that it cannot pull downward on any body nearly so hard as our earth can, and so on Ceres everything would weigh very much less than here.

If we could stand on one of the smallest asteroids, which are only as large as large mountains, we would hardly feel its pull at all. A 100-pound boy would there weigh only four ounces. He would find it very hard to walk without pressing so hard on the ground with his feet that he would be sent much higher up than he wished to go. He could easily throw a stone so far that it would leave the very little world and never come back again, but he could do something else much more wonderful than this. He could make so hard a jump that he himself would fly entirely away from the little world. But this would be a very unwise thing for him to do, because he would always afterward move around and around the sun in a great path with nothing to rest upon, unless sometime he might happen to pass so near another asteroid that he would begin to feel its pull and finally fall down upon it.

HOW ASTEROIDS ARE FOUND.

Although more than seven hundred of these little bodies have already been found, astronomers are still searching for more of them. They used to do this by first choosing some little square part of the sky and carefully measuring the positions of all the stars in the little square. When they had done this, they began the work all over again and measured the positions of all the stars a second time. If they found that any one of the stars had moved, then they knew that that star was an asteroid.

But this way of hunting was very slow and uncertain. An astronomer might work for many months and measure thousands of stars and not find a single little planet. They now hunt for them in a different and beautifully simple way which shows them at once whether one of the little worlds is in the part of the sky which they are looking at or not. This new way is by photography; the astronomers find the asteroids by taking pictures of them.

The pictures are made by using three large telescopes all firmly fixed together in such a way that all three point exactly to the same part of the sky. Two of the telescopes are to take the photographs with and the third is to look through. This is called a Pointing telescope; there are two very fine spider threads stretched across each other inside of it and near the small end, so that when one looks through it at a star he sees the very fine lines too. All the time that he is making the photographs the astronomer must keep the point where the lines cross each other exactly on one of the stars. By doing this he keeps all three telescopes pointed exactly right. But if he did not do it the pictures would be spoiled, in just the same way that a photograph of a person would be spoiled if the camera were moved while the picture was being taken.

When the work is all finished the astronomer will have two photographs of some little part of the sky. The two pictures will be just alike and they will be all covered with little round dots which are pictures of stars. But if a little planet was there too, the picture of this would not be a round dot because the little asteroid was slowly moving all the time that the picture was being taken. Because the little body was not holding still, its picture would be a short, bright line instead of a dot.

Sometimes the plates with which photographs are taken are not quite perfect; they may have little lines or blurred spots on them which ought not to be there. So as soon as the astronomer finds a little line on one of the pictures, he looks at the other one to see if the line is on that too. If he finds it on both pictures he is quite sure that it was made by an asteroid, and he then measures its position with a much larger telescope. The new world moving through the sky has left its little trail on the picture as if it said, ‘‘Here I am, a new world: come and measure me.’’

THE LITTLE PLANET NAMED EROS.

In the year 1898 a picture was made at Berlin in just the way we have been telling about. On this there was a bright line so long that the little planet which made it must have been moving very fast over the sky. It was afterward found that the little body seemed to move so very fast because it was very near the earth when its picture was taken. And it was found that the new asteroid sometimes comes nearer to us than any other world in the whole sky except the moon. This makes it a very interesting little body to us, but it is a very important one too, because by measuring just how it moves when nearest to us astronomers can find out just how far away we are from the sun.

The new world was named Eros. It is a very small body, less than twenty miles through, and as its brightness is always changing it may not be a round world. Eros will next come nearest to us in the year 1931: at this time astronomers all over the world will be busy making many thousands of measures of it.

THE ZODIACAL LIGHT.

Sometimes on a clear, cold evening in February or March you may see a soft, faint light stretching up from the ground in the western sky. It will look brightest and widest at the part of the ground where the sun was seen to set, and it may reach almost all the way to the highest point of the heavens. But near the upper end and along its edges this strange light is very faint, and it is not often that any part of it shines so brightly as the Milky Way.

As the hours of the evening go on the light will slowly set, just as the stars do. If on another very clear, dark evening you see it again, it will seem to be in almost the same part of the sky as before, but its brightest part is really near the sun, and as the sun moves slowly around the sky among the stars it carries the light with it. This faint light may also be seen on the other side of the sun, stretching up from the ground in the east before sunrise.

For a long time astronomers could not find out what this strange light is. At first they thought it might be made by very little particles in our air, but when they found that it always lay along just the part of the sky over which the sun moved they felt sure that it must be made by something which is around our sun. And now we believe that there is a great swarm of countless millions of little particles between the earth and the sun and even reaching beyond the earth. The swarm is shaped like a very much flattened ball; the sun is at the center of the swarm at its widest part and the earth is near its outer edge. We see a faint light from the little particles because the sun shines on them, but whether they are like little grains of dust or whether they are very much smaller than this and almost as small as the little particles which are in the tails of comets we do not know.

There is indeed much that is still to be learned about this strange light. Sometimes it grows much brighter for a little while: some astronomers think that this is because there are then waves of electricity passing through it from the sun. And when a great comet drew near the sun in the year 1843, the light shone out so brightly that some people who did not know thought it was a part of the comet itself. At other times waves of light have seemed to pass along it, much like the waves we sometimes see in our beautiful Northern Lights.

One very interesting thing about this swarm of little particles was found out only a little while ago. For many years astronomers have known that the little world, Mercury, is always being pulled a very little by something besides the sun and the other planets of the solar system. The pulls of all these could be found very exactly, and it could be told just how Mercury would move under all these pulls. But Mercury did not move in just this way: there was still another very little pull which could not be accounted for. It was even thought that there might be another world nearer the sun than Mercury and if this world should ever be found they decided that it should be named Vulcan.

But Vulcan was never seen, and in time they became sure that there was no such world there. At last it was found that the little pull was made by nothing else than the millions of little particles which are in the Zodiacal Light. And although each one of these little particles is probably smaller than any little grain of which we can think, yet it was found that the pull of all of them together would be just enough to cause the little world to move exactly as it was seen to do.

CHAPTER XVII.

The Solar System.

WHAT MEN OF EARLY TIMES TRIED TO LEARN FROM THE STARS.

WITH Neptune, we complete the story of the worlds which are near neighbors of our own. Our sun with the eight little planets moving around it is a very little island, all alone in the great star cloud. As we stand on Neptune we are at the very outermost edge of this island. Behind us are all the interesting worlds about which we have been learning, some of them made warm and pleasant by the heat of our great sun, and some of them even now worlds in the making, which will not become solid as our earth is until many long ages have passed away. Here there is warmth and life and interesting change, but if we look outward from the edge of our little island what a different sight will meet our view! For millions upon millions of miles, there stretches out in all directions nothing but an intensely cold, dark region, filled with nothing alive, nothing warm; only swarms of little particles and stones moving here and there throughout it all, but all perfectly dark and far colder than the most intense cold we can ever obtain on the earth. Truly, if a traveler had visited all the worlds of our solar system and had at last reached Neptune, he might well hesitate before plunging into this cheerless and forbidding region. Yet we will soon learn that if he could safely cross it, he would probably find thousands of other sun-systems, many of them doubtless even more interesting and wonderful than our own.

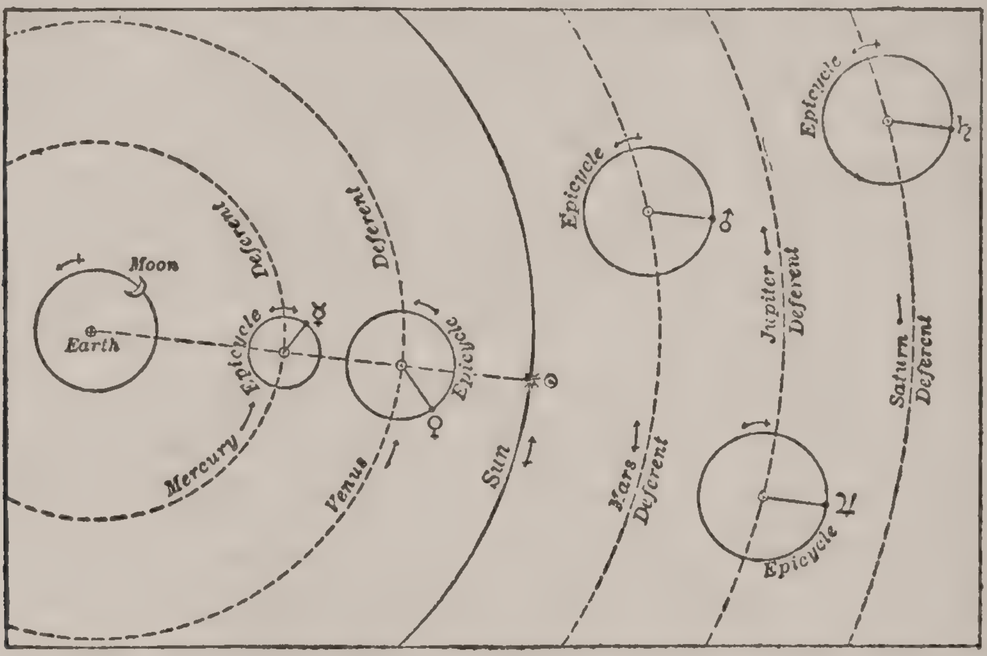
If we could stand out in space and look at our sun family, we would see all the planets moving regularly and smoothly along in their appointed paths, and after watching them for a time we would see very clearly that the paths of all of them are very nearly circles, and that the centres of all the circles are very near the sun. But as we must always remain on the earth, which is itself one of these moving bodies, their motions do not at first sight seem to us to be nearly so simple. Even if none of them moved at all, as we looked at them from our moving earth they would seem to us to be constantly changing their places among the stars, and when in addition to this they all have motions of their own, the actual paths which they follow over the sky are very complicated. Sometimes a planet is in the direction of one star group and sometimes in that of another; sometimes it seems to move westward over the sky, and then it turns and runs eastward again. If we watch it, night after night, and mark its different positions on a map of the sky, we will find that it has seemed to follow a very strange looking path among the stars,—a path having great loops and bends in it, and which does not look like a circle or ellipse at all.

For many centuries men watched the moving planets and studied these strange paths, but could not understand what they meant. In those early days they were very anxious indeed to learn how the planets are really moving, for they were sure that if they could do this they could foretell just where they would be seen among the stars on any date in the future. And they wished very much to be able to do this because they believed that the lives of men were influenced by the bodies in the sky, and that if they knew how the heavens looked at the instant a man was born, and that if they could foretell where the planets would be seen during his lifetime, then they could foretell all the important things which would happen to the man as long as he lived, and just when he would die. The study of how to do this was called Astrology, and men who studied astrology were called Astrologers. Kings and rich men were careful to have their fates told them by astrologers, and they would not begin any dangerous or important act without first learning whether the stars promised them success. The reader may perhaps remember how in the "story told by the tailor," from the *Arabian Nights,* the barber took the altitude of the sun with an astrolabe, and then informed the Stranger that a conjunction of Mars and Mercury which was then taking place demonstrated that a great danger was about to befall him.

Although we now know that astrology was a false science, and that the motions of the stars and planets tell us nothing about the lives of men and have no influence upon them at all, yet if men had not believed in it in the early days, they would not have measured the positions of the heavenly bodies so carefully as they did, and it might have been a much longer time before the true nature of our solar system was found out. But the many careful observations and records which they blindly made were to lead us, not only to a true understanding of how the worlds are really moving, but to the discovery of the great law of gravitation, which governs all the bodies of our universe and reveals to us the wonderful history of them all for countless ages of the past or of the future. How much more wonderful a thing it is to do this than to be merely able to find out signs of good or evil omen in the sky! The old astrologers hoped by their studies to light a little candle of truth; they did not know how, before long, the glorious sun would rise.

HOW MEN SLOWLY LEARNED HOW THE PLANETS ARE REALLY MOVING.

From the strange way in which the planets seem to move among the stars, men tried for many centuries to find out in what kinds of paths they are really moving. But for a very long time they made the mistake of supposing that our earth is fixed and motionless in the center of things, and that all of the heavenly bodies are moving around it. Nearly two thousand years ago, a great astronomer named Ptolemy taugh that the sun and moon were moving around the earth, and that all of the planets were moving around the earth too, but that the last moved in a very curious way indeed. He thought that each planet was moving around a very little circle, just as a fly might walk around the edge of a little wheel, and the centers of all the little circles, or wheels, were moving around the earth in much smaller circles. By choosing the large and small circles just large enough, the strange, irregular motions of the planets over the sky could be accounted for.



The paths of the Sun and Planets as they were described by the ancient astronomer Ptolemy. It was thought that the Planets moved around the small circles, and that each small circle moved around the Earth in a large circle.

For thirteen centuries, men thought that the heavenly bodies were really moving in this way. But as they observed them more carefully they found that if a body moved around one of the little circles or wheels, it would not be seen to move over the sky just as the planets do. And so they had to add wheel after wheel, until at last their picture of the solar system looked like a most intricate piece of clockwork. It was not until about four hundred years ago that the astronomer Copernicus showed how much more easily it all might be explained by supposing that the earth and all of the other planets are moving around the sun. He thought that their paths were circles, but sixty years later the great Kepler showed that their paths are all really ellipses.

For a long time men could not believe that our great earth is really moving. But soon the telescope was to be invented and they were to learn that the little points of light called planets are all moving worlds, some of them much larger than our own. And the sun was found to be wonderfully much larger than all the worlds together; they were to learn that it would require more than one million earths as large as ours to make one body as large as the sun. Surely, it is far more reasonable to suppose that our little earth is moving around the great sun than to believe that our earth is the center around which the sun and all of the other worlds revolve.

But why do all the worlds move regularly along in the particular curves called ellipses? Is it not a very strange thing that they should forever follow these great paths in space? What is it that keeps them moving, and why are their paths of this particular shape instead of some other? The answer to these questions was discovered by the immortal Newton. He clearly proved that if any body is seen to be moving along an elliptic path, then the force which causes it to move is certainly nothing else than the force of gravity. And, on the other hand, if we know, as we do, that the force or pull of gravity is always being exerted by the sun, then we can prove in what path any body must move, and that it cannot possibly move in any other path. And all of the complicated motions of the planets and comets, the motions of far distant systems of suns, the growth of worlds, the cause of their heat, and thousands upon thousands of other wonderful things which we see in the sky, are all made clear to us by our knowledge of how gravity is always acting. The discovery of the Laws of Gravitation is justly believed to be the greatest single discovery that any man who has lived on the earth has ever made.

WILL OUR SOLAR SYSTEM EVER BE DESTROYED?

If we study the path of a moving planet with great care, we find that it is changing a very little. The path of the earth at the present time is each year getting a little rounder, and each year we are a very little farther away from the sun than we were the year before. And we can see that the paths of some of the other planets are growing narrower, and that these worlds are very slowly drawing nearer to the sun. These changes of the path of a planet are caused by the very small pulls upon it of the other planets which disturb it in its motion.

All of these changes go on very slowly, but if they continue long enough it is clear that the paths in which the planets move may become completely changed. The path of Jupiter, for example, might become so narrow that it would cross the path of the earth; at some distant time the great planet might collide with ours and then our world would be entirely destroyed and swallowed up by its far larger neighbor. Or the planets which are now drawing very slowly nearer the sun, might in time get so near it that they would actually fall upon it and then their lives as worlds would be brought to an end. A century ago men studied the changes which are going on with great interest, for they thought it not unlikely that in the course of a very long time all the worlds of our solar system might in this way be entirely destroyed.

But the great astronomer Laplace first showed that this will almost certainly never happen. As all the little changes of the paths are caused by the disturbing pulls of the planets, he was able to find by a wonderfully difficult computation just what these pulls would do. And he found that although a path might change in one direction for a long time, yet it would at last begin to change again to what it had been before, and that the whole amount of the change would be very small. Thus the path of our earth is now growing rounder. In twenty-four thousand years it will be an almost perfect circle, but then it will begin to grow narrower until, in forty thousand years, it will be again of the same shape as it is now. At the end of sixty-five thousand years it will be at its narrowest, but even then it will be almost a circle; it can never become a very narrow ellipse. At the end of this time it will again begin to grow round, and so it will change back and forth, over and over again. And he showed that the paths of all the planets and their distances from the sun are changing in this same way. Though a planet may be now drawing a very little nearer to the sun, yet after a time it will begin to move farther away, and so it will continue to draw first nearer and then farther away and then nearer again, but it will never fall into the sun or collide with another planet.

It is a wonderful achievement that from a profound study of the discovery of Newton we are able to look for hundreds of thousands of years into the future, and to see just how the worlds of our solar system will be moving at that remote time. It is true that as no man can carry out the figures of any computation until it is absolutely accurate, we cannot say that at the end of many millions of years our system of worlds may not be destroyed by their various pulls upon one another, but we believe it very improbable that this will ever happen. And we believe that before that time our sun will have become a cold and dark star.

If our solar system is not disturbed from without, we therefore learn that it will very probably endure forever. Long after the sun has become cold, its eight little worlds will continue to move around it very much as they are moving now, although before that remote time they will all have become cold and dark worlds too. But we know that our sun is rushing through the cloud of stars which is around us with a speed of eleven miles a second. We have seen that at present it is moving nearly in the direction of the bright star Vega, but it will not pass by this star until it has pursued its journey for five hundred and fifty-eight thousand years. As the ages pass away and our solar system moves on and on in its endless journey, what may it not meet with? It may in time encounter one of the great clouds called nebulas, and as it ploughs its way through the cloud its worlds will be made so hot by the friction that they will be changed into masses of bright and glowing gas. Or it may pass so near some other star that the enormous pull of this body will actually tear it apart and its material will then be spread out to an enormous distance in the form of a great nebula. This will be told about more fully in a later chapter. In either case, a new solar system would then begin to form from the ruin of the old one.

But the nebulas are so far away, and the distances between the different stars are so very great, that it will be a very long time before either of the catastrophies which we have been describing can ever visit us. Age after age will pass away, and the planets will continue to move regularly in their appointed courses, guided solely by the wonderful power of gravitation which governs all the bodies of our universe.

A MODEL OF THE SOLAR SYSTEM.

Before we leave this wonderful little system of moving worlds to study other very different bodies, let us try to get a final view of it all as a whole. Let us try to clearly see how the sizes of the worlds compare with one another and how large the paths are in which they move. And there is no better way of doing this than to make a little model which will show them all.

It will be remembered that when we were trying to show how very large the sun is, we explained how we could make a perfect little image, or model, of the sun and the earth. We took a large ball, two feet through, to stand for the sun, and then we showed that we must take a little pea, only one quarter of an inch through, to stand for the earth. For the sun is just as much larger than the earth as the big ball is larger than the little pea. And if we want to show on our model the path in which the earth is moving around the sun, we must draw around the large ball a great circle four hundred and thirty feet across. We must think of the little pea moving around the large ball in this circle, and this will then be a model of the earth and the sun.

But now we will add all of the other worlds to our model. We will need plenty of room, for the larger planets are very far away. But if we have set our ball out on a great level plain, then the paths and sizes of all the other worlds will be as follows:

For Mercury, we must take a grain of mustard seed, and place it on a circle one hundred and sixty four feet across; for Venus, a pea on a circle two hundred and eighty-four feet across. The earth is, as we have seen, a pea as large as the last one, but on a circle four hundred and thirty feet across, while Mars is a very small pea indeed, only half as large as the others, moving on a circle six hundred and fifty-four feet across. Then we must add seven hundred grains of sand moving in circles one thousand to one thousand two hundred feet across to stand for the asteroids, a moderate sized orange on a circle nearly half a mile across to stand for Jupiter, and a very small orange on a circle nearly twice as large to stand for Saturn. Uranus will be shown by a rather large cherry on a circle a mile and one-third across, and lastly, Neptune will be a good-sized plum moving in a round path so large that the distance across it is no less than two and one-half miles.

Truly the model which we have made takes up a great deal of room. When we think of our image of Neptune, moving along in its path a mile and a quarter away from the ball in the center which stands for the sun, we begin to understand how very much spread out our solar system is. And yet it is solely the pull of the distant ball which governs the motions of all these worlds. To show the very nearest star on our model we would need to take another ball and place it more than eight thousand miles away,—entirely on the other side of the earth.

CHAPTER XVIII.

Visitors to Our Solar System—Comets, or Hairy Stars.

HOW COMETS SOMETIMES VISIT OUR SUN.

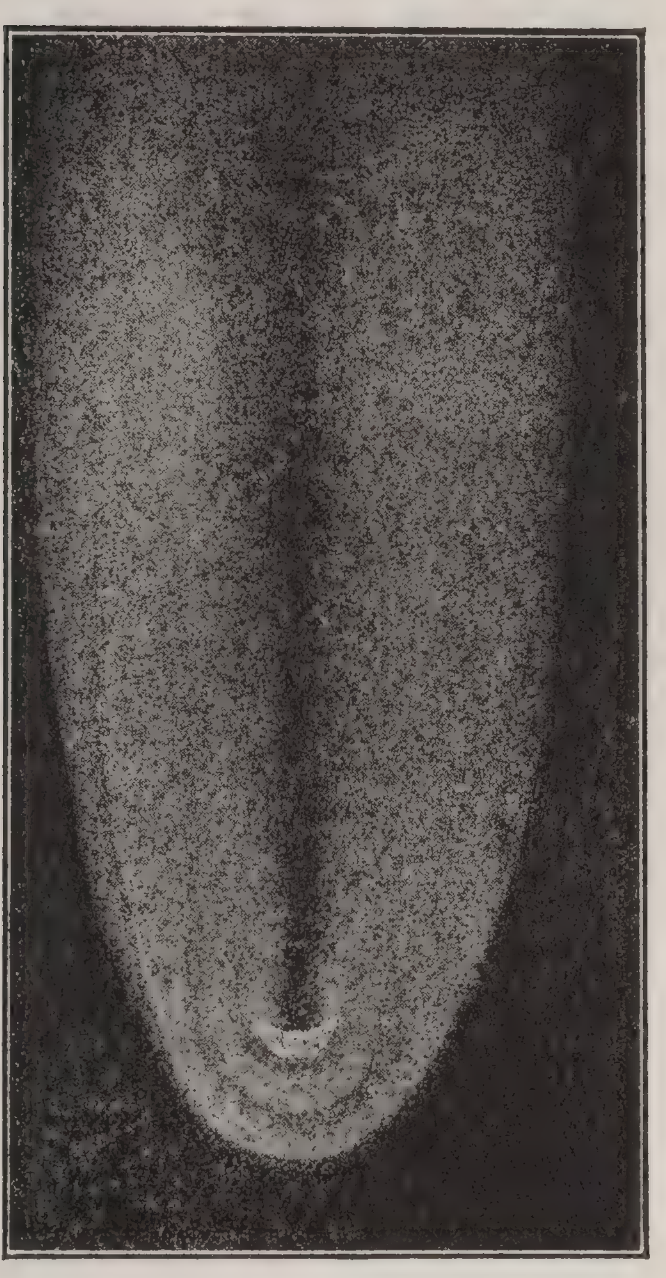
IN the earlier chapters of this book, we have told you about the sun, that great glowing ball of amtter which gives out the light and heat that make life possible on our earth. And we have told about the planets, Venus, Mars, Jupiter, and the rest, and how these bodies, like our earth, travel about the sun in great paths nearly circular in shape, and how each one is held in its place by a mysterious force acting from the sun which we call gravity. Some of the planets have still smaller bodies traveling about them, just as our moon travels about the earth, and these we call moons or satellites.

Now we may think of the sun and the planets with their satellites as a large family in which the sun is head or governor, and the planets are children, and if we do this, we should have to think of the little satellites as the grandchildren. The members of this family have belonged together for millions and millions of years. No new planets have joined us and none of the old ones have gone away. But this family sometimes has visitors, often very strange looking ones, and these visitors are called comets. They come from a very great distance, from a part of the sky many millions of miles beyond the planet Neptune. They are drawn in among our worlds by the force of gravity, that is, by the same attracting power of the sun which holds the planets in their places. They go near to the sun, pass very swiftly around it, and then usually go far away into space, never to return.

These comets are very strange looking bodies, and quite different from the planets, whether we look at them with the naked eye or with a telescope. When we see a planet in the sky at night, it looks just like a very bright star, but we can always tell it from a real star because if we watch it for a few evenings we can see that it is moving over the sky. If we look at a planet with a telescope, we see a small, round, bright disk with a sharp, clear edge which looks like a very tiny moon. But a comet always looks very different from this. The best way to tell what a comet looks like will be to describe one; they do not all appear alike, but yet they have general resemblances by means of which we can always recognize them. And so we will first tell about a most beautiful comet that suddenly appeared in the sky during the last century. It was first seen by an Italian named Donati, and so it is called "Donati's Comet."

When this comet was most brilliant, it had a bright, star-like head, which was closely surrounded by a thin cloud of light, as if a star were shining through a ball of mist or fog. Streaming out from this bright head there was a long beam of light, shaped like an old-fashioned scimitar, and this great light extended half way across the whole sky. It was narrow close to the head, but widened out farther away from it. This wonderfully large, bright band shone out in the sky for many weeks, rising and setting just as the stars do; but its shape was always changing, and at last it grew so faint and small that it could not be seen any longer; then men knew that the beautiful comet had left us. While two or three comets have been more brilliant than this, none has been more impressive, and none more admired. It appeared more than fifty years ago, and not many people now living remember seeing it, but if you can find some one who did see it, you will enjoy hearing him talk about it.

HOW COMETS CHANGE THEIR SHAPES.



The head of Donati's Comet as seen in the Telescope, September 29, 1858.

The parts of a comet have special names. The hazy ball of mist is called the Head, or Coma, the star-like center is called the Nucleus, and the long streamer of light is the Tail. Not every comet has all these parts, for some have only a coma without any nucleus or tail at all, but such comets are usually very faint and can be seen only with a telescope. Even the same comet is always changing its shape and appearance in a very striking and wonderful way. We will soon tell how the beautiful Donati's comet looked when it was first seen and of what a very different looking comet it afterward became, but before doing this we must tell the meaning of a word which we often use when we describe the path of a body which is moving around the sun. This world is Perihelion, and it means the position of a comet when it is nearest the sun. We say that a comet is ''in Perihelion'' or that it is ''passing through Perihelion,'' and these words mean the same thing, namely that the comet in its motion has reached the point where it is nearest to the sun.

The remarkable comet of Donati was discovered on

June 2, 1858, at Florence. When Donati first saw it, it looked just like a little, faint, round cloud: it then looked only one-tenth as far across as the distance across the full moon. This means that the comet consisted of a coma only; it then had no tail or nucleus,—nothing but a round, cloud-like head. It changed very little for several weeks, but after this time a faint, star-like point began to show itself which grew gradually brighter, and still later a tail began to appear. Early in September, nearly three months after it was first seen, the comet grew so bright that it could be seen with the naked eye.

It continued to grow in size and brightness, until in October, it became a most wonderful and brilliant object. It remained thus brilliant for two weeks, and then it began to grow fainter and smaller much more rapidly than it had increased. It finally faded from view and was last seen on March 4, 1859. Thus we can say that comets begin as little patches of mist, grow gradually until they become magnificent objects in the sky, and then fade away and are not seen again.

HOW COMETS SEEM TO MOVE OVER THE SKY.

We have not finished telling about Donati's comet yet, because there are many things we wish to learn about a comet besides its change in appearance. In the first place we want to know in what part of the sky it was seen and whether it stayed among the same stars all the time, or whether it moved over the sky as the planets do. The astronomers of that time have made records which show exactly where it was seen night after night, and if we mark all these places on a star map we find that it did really move very rapidly, but that its path carried it to a part of the sky where the planets are never seen.

When the comet was discovered it was in the group of stars called Leo: then it moved, rather slowly at first, a little to the northwest under the Big Dipper, until in September, when it could be seen with the naked eye, it was directly under the bowl of the dipper. From this point it began to move rapidly toward the southwest, until on October 5 it passed exactly in front of the bright star, Arcturus. This was the most wonderful sight of all those seen during the visit of this extraordinary comet, for the star was seen shining through the tail, quite near to the head, and almost undimmed in brightness. It made the head look more like a jewel than ever, and even the astronomer who sees so many interesting sights in the heavens was forced to express his admiration, and called it "The most majestic celestial object of which living memories retain the impress."

After passing Arcturus, the comet moved through the star groups of Serpens and Ophiuchus, and then still farther south until it could be no longer seen by people who were north of the equator on the earth. Thus we see that in general a comet appears suddenly and unexpectedly, moves through the sky, sometimes slowly and sometimes rapidly, and finally disappears. This is the history of all comets.

THE PATH OF DONATI'S COMET AROUND THE SUN.

There are still other facts that we can learn from the study of this interesting comet. We have found how it seemed to move among the stars and now we will tell how it moved about the sun. To make this quite clear it will be well to recall first how the planets move. You have learned that they all move around the sun in curves which are called ellipses, and which are not very different from circles. Now if we watch a planet every night to get its motion, we will not see it move along an ellipse in the sky, and the reason is that the earth with ourselves on it is moving around the sun. It is just as if there were two merry-go-rounds moving around, one inside of the other, the inner one going a little faster than the outer one. If you are on one and your friend is on the other, he will seem to move backward and forward in a very peculiar way. To find exactly how a planet moves around the sun, we must make several observations of it with very great care, and then by a long calculation we can find out what its path really is.

We must use just the same method to find the path of a comet. We must locate it very carefully among the stars with a telescope, and then calculate its true path. When this was done for Donati's comet, the astronomers found out some very interesting things about it. When it was first seen it was two hundred and forty million miles away from the sun, that is, half as far away as Jupiter. Its perihelion passage occurred on September 30, and at this time it was only fifty-four million miles away from the sun, or a little more than half as far away as the earth is. It was found that its path was a very long and narrow ellipse, so that when farthest away from the sun it was more than five times as far away as Neptune, and that the time which it spent in passing around its enormous path was more than two thousand years. Thus the nine months during which it could be seen from our earth was only a tiny fraction of the time which it spends in its long journey.

When you read these numbers they will not mean much to you, but if you can make a picture of the path of the comet you will get a much better idea of them. To draw this you will need a table nearly forty inches long; and first of all draw on it a straight line the whole length of the table and about ten inches from the front edge. Next, measure off a distance of six inches on the line from the right-hand end and drive a tack or a pin at this point: this will be the position of the sun. Then measure along the line thirty-three inches farther, place another tack or pin there, and this will show you where the comet is when it was farthest away from the sun. We call this position of the comet

Aphelion because that means ''away from the sun,'' just as Perihelion means ''near the sun.''

Now take a piece of paper and draw a circle on it one foot across, and also draw a very tiny circle only two-fifths of an inch across, but with the same center. Lift up the tack or pin which represents the sun, put it through the center of the two circles, and put it back in its place on the table. The two circles are the paths of the earth and Neptune; the small one is for the earth and the large one for Neptune, since Neptune is thirty times as far away from the sun as the earth is.

Next we will draw the path of the comet. Just to the right of the sun make a tiny mark on the paper a tenth of an inch away from it. This will be the perihelion of the comet, which we learned was a little more than half as far from the sun as the earth is: we have put the earth one-fifth of an inch from the sun, and we must put the perihelion half as far. Thus far we have the two ends of the comet's path, but we want to know how far out to the side it goes. Find the point on the line which is half way between perihelion and aphelion, and from this measure off one point three inches above the line and another three inches below it. Now draw a curved line from perihelion through the upper point to aphelion and back to perihelion again through the point below the line, and you will have a picture of the path of the comet.

WHY THE TAIL OF DONATI'S COMET SEEMED TO STRETCH HALF WAY ACROSS THE SKY.

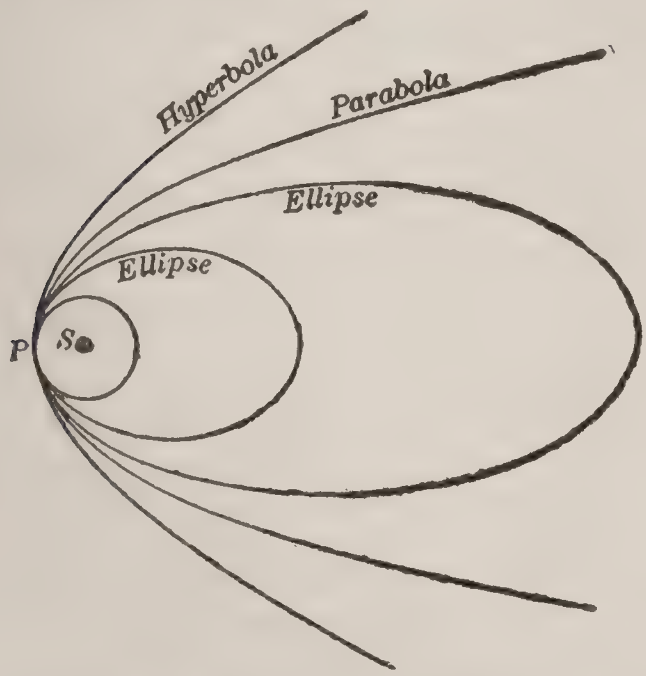
Just one thing more we must explain about Donati's comet, and we shall have finished its story. Why was it that we saw the tail so splendidly? The reason can be best made clear by using a simple illustration. Suppose that a long train of freight cars is standing on a railroad track and that you are there too, close by the engine. If you look at the train you can see the engine and you know that there are cars behind it, but you cannot tell the length of the train. If you want to find out just how long it is, you must walk out into the field away from the track and then you can see the whole train very well.

So it is with a comet's tail. It is stretched out behind the comet, always pointing away from the sun, and if we are in the right position, that is if we are off to one side of the tail, we can see it very well; but if we are nearly in line with the tail itself we do not see much of it. Donati's comet was in just the right position for us to see it best and that is why the tail appeared so long and beautiful. This is not true of all comets, as we shall see when we come to describe some of them.

There is one thing about Donati's comet which is very different from nearly all comets. We have seen how it is moving around a great elliptic path and how it spends two thousand years in making the journey around once, so that we believe that it will be seen again by the people who will be living on our earth two thousand years from now. And in the same way we know that it should have been seen two thousand years ago, that is, about the year 142 B.C. A great comet which was probably this same one was really seen in the sky in the year 146 B.C. But most comets after passing around our sun never come back again at all; we see them for a little while when they are near us, and then they go away into the great star cloud and we never see them again. Such comets do not move in round ellipses, but in another kind of curve which is called a Parabola.

THE PARABOLA.

If two boys are out in the field playing ball, you will notice that the pitcher does not throw the ball directly at the catcher, for if he did it would fall to the ground before reaching him, unless they were very close together or he threw it very swiftly. Instead, he throws it a little upward so that the ball rises and falls, sometimes higher and sometimes lower, just as he aims it. If you could draw a picture of the path of the ball through the air and should show it to a mathematician, he would tell you that it was a Parabola, and that every object thrown up into the air will move along such a curve before it falls to the ground. He would tell you also that the parabola is an open curve, because the ball will never go back to the place it started from. A circle on the other hand is a closed curve, for if you tie a stone to a string and whirl it around your hand the stone will always come back to the starting point, and an ellipse is a closed curve too. The two halves of an open parabola are called Branches, and they are just alike. The path of the ball as it moves up in the air is one branch, and the path as it falls to the ground is the other branch. These two branches separate more and more the farther the ball is thrown.



The different kinds of paths in which Comets move. The outer path is called a Hyperbola; the next path is a Parabola. These are both open curves, and a Comet moving in one of them would never return to the Sun. The point *P* is the Perihelion of all the curves.

Nearly all comets move along great parabolas, whose smaller ends pass around our sun and whose branches stretch far out into the great star cloud. They move along one branch as they draw near us from the depths of space, and as they approach the sun they rush along ever faster and faster. At last they swing around that body, and then they begin to recede into space again, moving along the other branch of the parabola as they go. As they draw away from the sun they move more and more slowly, and at last their distance from us becomes so great that we can no longer see them, even in the most powerful telescopes.

WHERE COMETS COME FROM.

We have seen that our sun with its family of worlds is like a very little island, all alone in the great star cloud. We have found that even if we could travel so wonderfully fast as light does, so fast that we could pass eight times around our whole earth in one single second, yet it would take us more than four years to make the journey to our very nearest neighbor among the stars. This distance is so very great that we who must always live on our little earth cannot possibly understand it, and yet it is distances even greater than this that separate the stars from one another.

What there is in this very great space between our sun and the nearest star, and between the stars themselves, we do not certainly know. We are quite sure it is not entirely empty, but think it contains much matter which has not collected into one large body like the sun, or even into smaller bodies like the planets. This matter may be in little bunches of different sizes, here and there, some very small and some quite large. Probably they are not very close to one another, especially the large ones, though perhaps the small ones are more evenly scattered. These bits of matter are not stationary in one place, but are all in motion, each one in a different direction. They do not go back and forth like gnats in a swarm, where each one is trying to dodge the others, but there is plenty of room around each one for it to move without any hindrance. And we believe that each group moves on a straight line until it comes near some other bit of matter and then it is pulled away from its first direction.

It is from this region that the comets come. At some time our sun, in its journey through the great star cloud, happens to come so near to one of the little clouds of matter that the little cloud begins to feel the pull of our sun and to fall toward it. Faster and faster it falls, until at last it has been drawn so near us that we see it shining out brightly as a comet in the sky. But because our sun is moving, the comet will not fall onto our sun. It will miss the sun, swing around it, and at last go out into the region of the stars from where it came.

HOW COMETS ARE ATTRACTED BY OUR SUN.

We have already learned how every little particle of matter in the universe is always pulling on every other little particle, and how this strange pull, or force, is called Gravitation. We have seen how it is the pull of the sun which keeps all the planets moving around it, and how the planets not only pull on their moons, but on each other also. It is exactly this same pull which causes the comets to move as they do, but the motion of these bodies is so peculiar, and so unlike that of the planets and moons, that to clearly understand it we must explain a little more about gravitation than we have already done.

In the first place, it has been found that the heavier the body is the harder its pull will be. If one body weighs twice as much as another, its pull will be just twice as great; if the earth were ten times as heavy as it is, it would pull down on everything on its surface ten times as hard as it does now. That is, a boy who weighs one hundred pounds now, would weigh one thousand pounds, or nearly half a ton then.

And in the next place, it is found that the pull of any two bodies on each other gets smaller and smaller the farther apart they are. But if they are moved twice as far apart, their pull is not made merely one-half as great; it is really made one-fourth as great as at first. If they are placed three times as far apart as at first, the pull is made only one-ninth as great;

if they are four times as far apart it is one-sixteenth as great, and so on. So we see that when bodies are moved far from one another their pull becomes very weak indeed.

Thus the larger a body is the stronger its pull is, but the pull of gravity does not depend on size alone, but on distance too. The sun pulls on the earth and on Mars, but its pull on the earth is much stronger because the earth is much nearer the sun than Mars is. And both Mars and the sun are pulling on the little moons of Mars, but Mars, in spite of the fact that it is so very small, pulls them harder than the sun does, because it is so much nearer to them.

These two laws about gravitation were discovered by the great astronomer, Sir Isaac Newton. He also discovered a wonderful law known as "The First Law of Motion," which is that every body in the universe will either remain always at rest or else it will keep always moving along in a straight line and at a unifrom speed unless there is some force acting upon it. Our sun is moving along a nearly straight line through the great star cloud with a uniform speed of eleven miles a second. Its path cannot be exactly a straight line because it is being pulled by the inconceivably distant stars. But these are all so very far away that their pull is very slight indeed and we have so far been quite unable to see from our measures that its path is not perfectly straight.

And so any little cloud of matter out in space will be drifting along in an almost straight path. At last it may draw so near our sun that the pull of that body on it will be greater than the pull of all the other stars together. If this happens it will begin to turn toward our sun, at first very little because it is so very far away that the pull is very feeble, but afterward more and more, until at last it is falling almost directly toward us. And the nearer the sun it comes the stronger the pull will be, so that it will keep moving faster and faster. When it reaches perihelion, the pull of the sun will be so very great that it will move very fast indeed, but after it passes this point and begins to draw away from the sun its motion will continually become slower.

A JOURNEY AROUND OUR SUN.

All of stellar space is filled with bits of matter separated from each other by wide distances, and all moving along in straight lines in accordance with Newton's law of motion. Many of these bits of matter are small, but some of them may be as large as the satellites, or even much larger, though they are not so compact; the larger ones are very probably simply great clouds or swarms of smaller particles. Let us suppose that there is some sort of spirit living in one of these larger swarms traveling through space, and that he has lived there for a long time. Let us suppose, too, that he is an intelligent spirit and knows a great deal about the motions of the heavenly bodies. For ages he has been traveling at a very leisurely rate along a straight line toward the bright star Sirius, and he watches it just as the pilot watches the beacon, and hopes some day to get quite near it. He says to himself, "I hope I am not going to pass near some other large body, because then I shall be pulled about and shall not be able to reach that bright star toward which I have been aiming for so many years."

Just then he begins to notice that his course is not so true as it was, and he begins to feel a little hurried. Off in another direction a star which he had been noticing for some time, appears to be a little brighter Offi in another direction a star which he had been strange star grows larger and larger, and even gives off heat, which bothers him a great deal, for out in space it is very cold. Soon the new star begins to show a small, round disk, and there is a faint light glowing about it all the time, so that he can not see the stars near it. He sees the planets, at first only the larger ones, and wonders at them, for from interstellar space they are too small to be seen. It gets hotter and hotter, and he becomes quite uncomfortable, especially as there seem to be all sorts of queer motions in his home. A little gas is being formed and he is afraid of being smothered. He appears to be going straight at the terrible sun which grows brighter and larger every moment, but being an imaginary spirit, and something of an astronomer, he has discovered that he is travelling in a parabola, and knows that even though he may go very near the sun, he will not fall into it but will skirt around it and travel away again into space. He hopes to be able to live through all his adventures and enjoy the recollection of them afterwards.

He is hurried along faster and faster. Such a cloud of gas envelopes him that he can hardly see through it, but he manages to get away to the side opposite the sun and there he sees a wonderfully vast stream of light stretching out behind him. Faster and faster, and nearer and nearer to the sun he gets, until he can see the great sun-spots and the fiery prominences, and he even goes very near to the corona. He feels quite safe, but is very glad when he knows that his speed is slackening and realizes that the danger is over.

What astronomers believe to be the real history of a comet, we have tried to make more vivid by this story of an imaginary traveler. The mass of matter which composes it is moving on through space in a straight line, in a direction which brings it within the influence of the sun. The pull of the sun will tend to draw it in, but it has to act against the motion which the body possesses, and as a result it makes it describe a parabola. This curve brings it in toward the sun, carries it around it with enormous rapidity, often very close to it, and then takes it away on the opposite side, off beyond the limits of our system, and beyond the attracting power of the sun. It then travels along in a straight line again, but in a very different part of space and in an entirely different direction, toward another star. Thus its journey is one that never ends. It comes from inter-stellar space and returns to it again. All that we see of its path is the small part of it near the sun, but we have such faith in the laws of motion that we feel justified in telling the rest of the story.

Later on we will tell you how it is that some comets stay in our system, but the last few pages have been rather hard reading so now we will write something that is easier to understand. You want to know how comets are discovered, and how the discovery is announced.

HOW COMETS ARE DISCOVERED.

Very often comets are discovered by accident. The astronomer is looking for something else, sees a bit of cloud among the stars in his telescope, and watches it for an hour or so to see if it moves. There are other bodies in the heavens which look a great deal like comets but are called nebulas: unlike comets however, these are so very far away from us that they do not seem to move but remain in the same spot all the time. When the astronomer sees a little cloud in his telescope, and is not sure whether it is a comet or a nebula, he first looks at a list of nebulas to see if there is one in the spot where he is looking. If there is not, he makes a careful measure of its position, and if in the course of an hour it has moved among the stars, he is sure he has discovered a comet.

The next thing to do is to get the news to the other astronomers as quickly as possible, for comets are visible such a short time that no time can be lost, and hence the news must go by telegraph. It is sent to a central observatory from which place it can be re-sent to many other astronomers, and published in the newspapers. The central bureau in America is the Harvard College Observatory, in Cambridge, Mass. From here it is sent by cable to the Astronomische Nachrichten in Kiel, Germany, the central bureau in Europe, from which place it is forwarded to all the European observatories.

Now in order to describe the place of a comet, a great many figures must be sent, and in a telegram each word counts as a whole word; for example, thirty-five counts as two words. This would make it very expensive to send many telegrams explaining where to look for a comet, and therefore some sort of telegraphic code is used. There are several kinds, but the following is the one recently published by the Harvard Observatory. Each number is represented by a syllable, and the syllables are then put together in the form of words and can be sent at a much cheaper rate than the full form. The telegram has very queer looking words, and if the operator did not know that it came from a harmless astronomer, he would be inclined to report it to the police as being something very dangerous. Here is the list of syllables and a message:

1	2	3	4	5	6	7	8	9	0
ba	de	fi	go	ku	am	en	ip	ot	ux

Comet uxamuxbaba kubagofide deuxfienba godedeuxen badegoipde fidekuuxfi.

William F. Anderson.

Translation.

William F. Anderson announces that a comet, visible to the naked eye, was discovered by him, January 15, 14 hrs., 32 min., Greenwich Mean Time, in right ascension 20 hrs. 37 min. 14.2 sec. and declination 7° 12′ 48″.

If you count the separate words in the complete telegram, you will see that it would cost a great deal to send such a message. There is one objection, however, to the code, and that is, it is very easy for the operator to make a mistake in a word. You will see how this is if you try to write it out for yourself, how you have to watch every letter. Whereas if you know the words, you can spell them out for yourself very easily. At each observatory, can be found an explanation of the code, and if only one letter is wrong it can be easily corrected.

We have not finished telling you about the discovery of comets, for not all are found accidentally. Some astronomers make a special point of looking for them and have a telescope made expressly for the purpose called a "Comet-seeker." The telescope is very short, and this makes it take in a great deal of the sky at a time and give a bright image. It is so mounted that it can be swung back and forth very easily in a direction parallel to the ground. You know that comets are brightest when they are near the sun, therefore the astronomer must look in that region of the sky for them; that is, he must look in the west soon after sunset, or in the east before sunrise. In this way, many comets are "picked up" and the astronomer is said to be "sweeping" for them. I suppose this word is used because he moves his telescope back and forth as one swings a broom. Several astronomers have discovered a great many in this way. In America, during thirty years, Professor Brooks discovered twenty, and Professor Barnard, nineteen. An Italian observer named Pons, discovered twenty-seven in twenty-four years.

HOW COMETS ARE NAMED.

Sometimes comets are discovered on photographic plates. One of the most interesting of these appeared in 1908, and was known as Comet 1908 c, (Morehouse). This shows us how we name a comet, for each comet must have some sort of a name in order to distinguish it from any other comet. In order of discovery during each year the letters of the alphabet are given to them, as 1908a, 1908b, etc., often as far as 1908g or h: 1908h would mean the eighth comet discovered during 1908. Then the name of the discoverer is attached as above, 1908c, (Morehouse). If a comet becomes very well-known on account of its brightness or because there is anything peculiar about it, it is generally called by the name of the discoverer, just as we spoke of Donati's comet, though this latter is often called the "Great comet of 1858."

Sometimes a comet is seen by two observers at about the same time, and then it may have both names attached, as Comet Borelli-Brooks. If it is so bright that a great many see it at once, it must be known by its other name, like the fine comet that was seen early in the year 1910. This was seen first by two railroad men in South Africa one morning before sunrise, close to the sun. They knew that Halley's comet was expected to appear sometime during the year, and thought this was it. A railroad official telegraphed the news to the director of the observatory at Johannesburg, but he knew it was not in the right place for Halley's comet, and hence it was called Comet 1910a, and it will always be known by that name. This name, which includes the letter of the alphabet, is only temporary, for after a year has ended, all the comets discovered during that time are re-named, this time with Roman numbers giving the order in which they make a perihelion passage. Thus Donati's comet is 1858 VI, Morehouse's comet is 1908 III, and comet 1910a, has not yet received its final name.

CHAPTER XIX.

Visitors to Our Solar System—Continued.

SOME BRIGHT COMETS WHICH HAVE VISITED US.

THUS far we have described only one bright comet, but though that was one of the most beautiful seen during the last century, there were several others which were called "Great Comets" and some of these were as bright and striking as this one. The finest of these were seen in the years 1811, 1843, 1861, and 1882.

The first one is mentioned, partly because it was so large and bright and partly because it was connected with the Emperor Napoleon, for it appeared during his invasion of Russia. It was visible for seventeen months, from March 1811 to August 1812. During its brightest period it was quite far north in the sky and hence could be seen to very great advantage, whereas comets, generally, are so near the sun that they can be seen only a little time after sunset or before sunrise. The tail of this comet stretched one-third of the way across the sky, and there was a bright planet-like center in the head. It was calculated that the tail was in reality more than one hundred million miles long, or greater than the distance from the earth to the sun. It was also known as the Vintage comet, because during the year 1811 the vines in Portugal produced such very fine wine that it became known as "comet wine," fixing its date as 1811.

The next great comet, and in some ways the most astonishing of all, was that of 1843. It was first seen close to the sun on February 28 by observers in the United States and Europe, and that not at sunset, but at mid-day. This fact shows its extraordinary brilliancy better than anything else that could be said about it. The planet Venus at its brightest can be seen in the day-time by those who know just where to look for it, if it is not very near the sun, but this comet was so bright that it attracted the attention of the casual observer. Any one who looked up in the sky near the sun could have seen it. In Italy, where the skies are very clear, persons who stood in the shadow of a building so that their eyes were protected from the glare of the sun, could even see the tail extending for a long distance across the sky. On the same day, just before sunset, it was seen by the passengers on an English ship near the Cape of Good Hope, appearing as a short, dagger-like object.

In those days news travelled more slowly than with us, and hence the observers in Europe had not heard of its discovery. Great was their astonishment when one evening after sunset the Englishmen saw a beam of light stretching up in the west, slanting low along the ground, and extending as far as Orion. It looked like an enormous search light, but set in a short time with the stars. The astronomers were quite sure that it was the tail of a comet, and that the head was below the horizon, but the people in general were greatly frightened and feared that something terrible was going to happen. Each night it was seen more easily, since it was rapidly going away from the sun, and in two days time the head was visible. This was not nearly so bright as the tail, an unusual state of affairs with comets, and besides, the brightest part of the tail was not directly at the head but some little distance from it. It was never so brilliant to the northern observers as to those in the tropics. In the north it lay rather near to the ground, but near the equator it stood nearly upright. It was more splendid than Donati's comet but not so beautiful in shape.

The most interesting account of this comet was given by an English general who was returning to

England from the Cape: "It was during our passage from the Cape of Good Hope to the equator, and when not far from St. Helena, that we first came in sight of the great comet of 1843. In the first instance a small portion of the tail only was visible at right angles to the horizon; but night after night as we sailed along, it gradually became larger and larger till at last up came the head. . . . It was a grand and wonderful sight, for the comet now extended the extraordinary distance of one-third of the heavens, the nucleus being perhaps about the size of Venus."

The same writer compares it later with Donati's comet and writes of the latter, "A very large comet made its appearance about this time, and continued for several weeks to be a magnificent object at night; it was, however, nothing to the one I had seen in the year 1843 when on the other side of the equator."

The path of this interesting comet was as astonishing as its appearance. Astronomers found that at Perihelion passage it was seventy-eight thousand miles from the surface of the sun, going nearer than any comet we know of, and that it rushed around the sun in only a few days. Its tail was found to be two hundred million miles in length. Truly if our imaginary spirit had been living on this comet he would hardly have trusted his own calculations when he saw himself getting so near the terrible sun; but the comet got away again in spite of its very near approach.

WHEN THE EARTH PASSED THROUGH THE TAIL OF A COMET.

The next comet on our list appeared in the year 1861. While not so imposing a sight as either of the preceding ones, it is particularly interesting because it is believed that the earth passed through its tail, though at the time nothing happened to suggest it. It was discovered first in the southern hemisphere, but moved rapidly north and was soon seen in England on the evening of June 9. Sir John Herschel in writing of this comet said that his attention was called to it by a neighbor who reported that some of his family had taken it for the moon. The next night Herschel himself observed it and stated that it was greater in brightness than any comet he had ever seen, not even excepting the remarkable ones of 1811 and 1858. The head was more brilliant than any planet except Venus at its brightest. Many other astronomers observed it on the same night, which happened to be Sunday. Two or three noticed that the sky had a peculiar glow, that the sun which had not yet set was shining with a feeble light, and in the churches candles had to be lighted in order to finish the service. The head of the comet was seen while the sun was still shining, and after it had set, the tail became visible and presented an unusual appearance, for it was spread out like a fan with several streamers radiating from the head, of such length that after it had set, they extended beyond the zenith. The two outer streaks were separated from the rest of the tail like the outer sticks of a fan.

The next night was quite cloudy, and on the next following night the comet resembled any ordinary comet. It was as if the fan had been folded up. When the astronomers came to calculate its orbit, they found that on June 30, the earth had passed through its tail; that on that date the comet was nearly in a direct line between the earth and the sun, about fourteen million miles from the earth. The tail stretched out in somewhat of a curve, to an extent of fifteen million miles, and thus the earth was about a million miles inside it. If this was true, then some of the material of which the tail was made up would lie in front of the sun and account for the dull yellowish glow that was seen. The strange appearance of the tail could also be explained. The tail of a comet is sometimes hollow like a cone; if the earth is inside of this cone the part of the tail that we see would look like a fan partly opened. To illustrate this think of the tail as being like a huge megaphone and imagine the earth to be a little inside the open end. Put your eye just inside of one and you will find if you look down toward the center that the part which you see is spread out like a fan.

THE FEAR OF COMETS.

In these days, when so many interesting articles are written on all sorts of scientific subjects, and when children are taught the facts of nature in school, it is hard for us to understand how people felt about comets hundreds of years ago and how very much frightened they were when a large one was seen. Nowadays when you see anything unusual, you ask your parents or your teacher what causes it, for you know that there is a natural explanation for everything you see. In former days people were not so well educated as they are now, and when they saw any strange thing in the heavens they thought it showed that they were going to suffer from great wars or dreadful diseases, and began to pray to their various deities to avert the dreaded event. Homer, a Greek poet who lived nearly two thousand years ago, wrote of a comet, "Like the red star that from his flaming hair shakes down diseases, pestilence and war."

When a comet appeared in the year 1528 it was described by a writer of that time as follows: "This comet was so horrible and frightful and produced such great terror among the populace, that some died of fear; others fell sick." And when one appeared in 1580, the historians wrote: "All the telescopes have been pointed for three days to the firmament; a comet such as has not been seen in modern times occupies day and night the learned of our Academy of Sciences. The terror is great in the town; timorous minds see in this the sign of a new deluge, considering, say they, that water is always announced by fire. . . .

Others discuss the question whether the wandering star does not announce the death of some great personage."

We now know that the coming of one of these beautiful and interesting objects is no more to be feared than the daily rising of our bright sun. We study them and watch them go through their various changes with the greatest pleasure, seeing in them only new evidences of the wonderful harmony which rules throughout all the bodies of our universe.

A COMET WHICH PASSED ACROSS THE FACE OF THE SUN.

The next great comet, that of 1882, was remarkable not only on account of its extreme brightness, but also because it passed directly over the face of the sun. The best observations of this unusual event were made at the cape of Good Hope, and they are very important, because they tell us a great deal about the density of the head of a comet.

This comet was first seen at five o'clock in the morning of September 7, by Mr. Finlay, one of the assistants at the observatory, and it was then quite bright, with a star-like nucleus. It grew brighter day by day and was observed independently in several different countries,—France, England, and the United States,—and finally was seen in full daylight not far from the sun. On September 17, as Mr. Finlay watched it, he saw that in all probability it would pass directly across the sun, and another astronomer was appointed to watch it too, with another telescope. It was visible all day long, appearing of a bright silvery color, in contrast with the sun which is usually golden. He used a piece of colored glass on the telescope, and by means of clock work kept the comet in the field of the telescope.

At half past four it began to get very close to the sun; ten minutes later the edge of the sun was in the field with the comet, and the comet was still undimmed in brightness and of the same silvery color. It crept rapidly up to the edge of the sun which was "boiling" badly, because it was not far from the ground, and at ten minutes of five the comet had disappeared, whether in front of the sun or behind it he could not say. Immediately he brought the whole image of the sun into the field and examined it with great care, but found not the slightest trace of the comet and came to the conclusion that it had passed behind the sun. The other observer made the same report. Several days later, when its path had been calculated, they learned that it had passed in front of the sun and not behind it, therefore their observation shows of what very thin material the head of a comet is composed.

The next morning the comet was seen again, but this time some distance away from the sun, appearing a most brilliant object in the sky and remaining visible during broad daylight.

You may wonder if there were not other observers who were watching to see the comet pass by the sun if it was such an important and interesting observation. An English astronomer followed it until it was quite close to the sun, when the sun became covered with clouds. In South America, at Cordoba, in the Argentine Republic, an American Astronomer, Dr. Gould, in charge of the observatory there, tells of his observations so interestingly that we will give his account in his own words, but first I wish to call your attention to the difference in time between Africa and South America. You know that when you travel west in this country, you have to turn your watch back an hour when you reach Buffalo or Pittsburg, and again, another hour when you go still farther west. When it is four o'clock in New York, it is only one o'clock in San Francisco. Since South America is so far west of Africa, when Finlay saw the sun nearly setting at the Cape of Good Hope, it was only eleven o'clock at Cordoba, and the sun was high in the heavens. Dr. Gould writes of the comet:

"September 17 the comet was very bright and easily found in full sunlight. At 10.40 a. m. it was necessary to use a shade glass on account of its proximity to the sun, and at 11 the sun and comet were in the field of view. . . . Later the comet was hidden by the disk of the sun and though I carefully scrutinized this . . . no token of the comet could be seen, nor could it be found during the afternoon. Early the next day its brilliancy attracted popular attention throughout the country and the 'blazing star near the sun' was the one topic of remark. Telegrams from all parts of the country came to me as well as from Chile and Uruguay calling attention to the phenomenon."

We have taken a good deal of space to tell about this one event because it is the only one of its kind that has been recorded, and hence it is of great importance. There were other facts in connection with the comet which we will therefore only mention briefly. Instead of having a single bright center or nucleus in the head, there were three spots, connected by a bright streak; the tail was not shaped like the ordinary tail, but was forked at the end like a fish's tail and large bright nebulous masses were twice seen outside of the tail as if they had been left behind by the comet.

The next bright comet was called 1910a, and we have already told how it was first seen. It was not visible long, and in the eastern part of our country clouds prevented it from being seen, but for a few nights it was a beautiful sight. Perhaps some of our readers may have had the pleasure of seeing it.

HOW MUCH COMETS WEIGH.

In the preceding pages we have told about a number of comets and have mentioned here and there different facts about them; about the enormous lengths of their tails and how they are so thin that a star can be seen through them, and about the wonderful transit of the comet of 1882 across the sun. What kind of bodies are these strange looking comets? How large are they, what are they made of; what causes their tails, and how can they change their size and shapes so quickly as they do? Before answering all of these questions we must explain the meaning of a word that we shall use many times: this is the word "Mass," and it means the quantity of matter in any object.

Suppose that we take two bags of the same size and fill one of them with feathers, pressing them down tight, and the other with stones. The bag full of stones will be very much heavier than the bag of feathers, even though they take up just the same amount of room. The reason is that there is more matter in the stones, that is, there is more "mass" in them than in the feathers: we say their density is greater, and by density we mean the amount of matter there is in some space that we select, say in a cubic foot. If a cubic foot of stone weighs more than a cubic foot of feathers, then its density is greater.

Why is an empty pail lighter than a pail full of water? You will think this a very foolish question, but it is not, for an empty pail is not really empty; it is full of air, and the pail full of water is heavier than the pail full of air because water is denser than air. Air is one of the lightest things we know. If you will think a moment, you will remember that heated air is lighter than cold air. On the Fourth of July, when you want to send up a paper balloon, it must be filled with hot air, and then it rises upward because the air inside of it is less dense than the air outside. We read much nowadays about dirigible balloons, and we know that they must be filled with some kind of gas that is lighter or less dense than air.

From these simple illustrations you can easily get the ideas of mass and density and can understand what we mean when we say that a comet is a body of enormous size, but of very small density. Some of the reasons why we know that this is so, you can think of for yourself. In the first place, we can see stars through the tail of the comet and they lose hardly any of their brightness. Donati's comet passed in front of the star Arcturus, which was seen close to the comet's head, and yet the star appeared as bright as ever. Then the comet of 1882 made a transit across the sun without showing a trace of its presence. And in the year 1861 the earth itself passed through the tail of a comet and very little that was unusual was noticed.

But there is another thing that clearly proves to us that a comet weighs very little indeed. This is the strength of its pull, or its gravity. The comet in its journey around the sun must pass near some of the planets and if its mass were in any degree in proportion to its size it would pull them out of their regular paths. But we do not find that any comet, even the largest, has ever disturbed any planet by its pull. And so we are fully assured that the mass of a comet is very small and the stuff of which it is made very thin and rare; thinner than the lightest whiff of smoke which floats away in the air. It is not probable that if the largest comet could be all pressed together and weighed, that it would be found heavier than an iron ball one hundred and fifty miles through. Yet although comets are so light, they may have many large stones and meteors in them, but these are not grouped very closely together.

HOW LARGE COMETS ARE.

The largest comet that we have so far seen was the comet of 1811; the distance through the head of this comet was more than a million miles. This means the entire head, for the star-like center or nucleus is always much smaller. In fact, for the comet of 1811 the nucleus was only four hundred and twenty-eight miles through. The head of this comet was therefore quite a little larger than the sun itself. The head of Donati's comet was two hundred and fifty thousand miles across, or about one-fourth as far as the distance through our sun: that of Holmes, seen in 1892, was more than seven hundred thousand miles through and was without any central nucleus at all. However, only the largest comets have heads so large as these; the great majority of them are from forty to a hundred thousand miles across, and in some of the faint ones the distance is hardly more than ten thousand miles. But if a comet were smaller than this it would hardly be seen from our earth, unless it happened to come very close to us.

So far in this chapter we have told you only about the large and beautiful comets, but there are very few of these. A very great number of comets have visited us which are so small that they could never have been seen except with a telescope. Many of these are so faint that they can only be seen with the very largest telescopes; they have no tails, and never develop even a nucleus. Probably there are very many of these which enter our system and go away again without our having seen them.

The size of comets as they move around the sun is all the time changing, and it is a very curious fact that the heads of comets usually grow smaller as the comets draw near the sun. The change in size is sometimes very great; sometimes the head of a comet is only one one hundred thousandth part as large when it is nearest the sun as it is when the comet is farthest away. Astronomers are not yet able to explain the cause of this remarkable change.

WHAT IS A COMET?

Astronomers believe that a comet is made up of a vast company of particles of solid matter which travel along together, somewhat like a swarm of bees. Most of these particles are very small. Some think that they are the size of pin-heads, and some think that they are as large as bricks or even rocks; and traveling with this cloud of little particles there may be others which are many miles through. Whatever the sizes of the particles may be, they are not very close together. They are more like the grains of sand in a dust storm than like the same amount of sand collected into a pail.

These little particles are in constant motion among themselves, and mixed up with them in the cloud there is always the very light matter called a gas. Beside this there is probably a great deal of matter there which is in the strange state that men now call the radiant condition; that is, very light matter which is very faintly shining. The whole cloud—particles, gases and meteors—moves along through inter-stellar space; there cannot be much heat in it, nor can it throw out very much light.

When the comet is drawn into our system, the pull of the sun causes the little particles in the head to move more violently; the whole cloud is stirred up by this pull, and it is much disturbed too by electricity that is caused by its changing, and it grows hotter and brighter. As it draws nearer the sun it shines more and more brightly, partly because of the electrical currents which pass through it, and partly because the sun makes it hotter. Astronomers do not yet know how electricity is made in the comet or what it will do. They know that the sun is a great center of electrical force, and that electrical currents pass from it through the solar system; it is these which cause our beautiful Northern Lights. When such currents pass through a very rare gas they make it glow with a peculiar kind of light, such as you may see in a doctor's office in an X-ray tube. We do not think that all the light of a comet's head is made in this way, but we are quite sure that some of it is. Comets always grow brighter as they draw nearer the sun, and fainter as they leave it, but often one will brighten up or grow faint without any apparent reason, in a few days or even in a few hours.

We may find out some of the material which is in the head of a comet when we study it with the spectroscope, that wonderful instrument which tells us so much about the sun. If we use this to examine the head of a comet and the brighter parts of the tail, we find that sodium is there, and also a gas which we call hydrocarbon and which is like the gas in our houses when it burns with a blue flame. Sometimes we see iron, and often another gas is present called Cyanogen, and which is poisonous to breathe.

But there is something else which we must explain about comets, and that is why their tails are always pointed away from the sun. They do not always lie in a direct line behind the comets, but usually curve away from the head and lag a little behind it, so that they look horn shaped. We think that a comet's tail is caused by an electrical force coming from the sun which drives away the very small parties of gas which are in the head. In Coggia's comet the action of this force was shown very nicely. There were streaks in the head, showing clearly that the different layers of gas were first driven from the head toward the sun and that they were then pushed away from the sun again. The same thing can often be seen in other comets.

COULD A COMET CAUSE HARM TO OUR EARTH?

Some people have been afraid that a comet might sometime harm us in one of two ways; either by running into our earth or by falling on our sun. But when we consider of what filmy material comets are made, we see that not much harm could come to the earth even if a comet were to strike it. The earth has already passed through the tail of one comet, and but few people knew that anything was happening. If we should strike one much nearer the head, some of the gases which are there would enter our atmosphere, but because our air is so much denser than they are it would act as a blanket and keep them away from the earth itself. Most of the solid particles in the head are probably so small and so far apart that if they struck the earth they would appear to us like a shower of shooting stars; each one of them would be burned up as it ploughed its way through the miles of air above us.

If a comet should fall into the sun, no harm could come of it, because the sun is so large and the mass of the comet is so very small. The little particles of the comet would become buried inside the great body of the sun, but they would make no change that we could see in its heat or appearance.

PHOTOGRAPHS OF COMETS.

Photographs of comets are taken nowadays which are much finer than the drawings of former times, especially in showing the nature of the tail and the changes which take place in it. But a comet is so faint that it takes a long time for the astronomer to take its picture, and since it is all the time moving, he must keep his telescope moving too, in order to keep up with it. When a picture is made, the comet shows very plainly, but the stars which are around the comet appear on the picture like little streaks of light. The telescope has clock-work attached to it which carries it along just as fast as the stars move, and we have seen how when the astronomer makes a picture of these, they all look like little round dots. But a comet is moving among the stars, and in order to photograph it he must move the telescope a little differently to keep up with it; and so the stars make little trails across the picture.

A photograph has some very great advantages over a drawing, no matter how carefully the drawing is made. The chief of these is that by making a very long exposure, a very faint object can be well represented which could hardly be seen with the eye, even if a skillful observer were using a large telescope. But if one is photographing a bright object, care must be taken not to leave the shutter open too long, or else the plate will be over-exposed and all the fine details will be lost. And so in making a photograph of a comet, if we make a long exposure for the tail, which is faint, then the head will be nothing but a bright ball of light and the finer markings which are seen in a drawing of it will not appear.

Photographs are generally taken to especially show the tail and its changes, and some very interesting things have been learned from them. For example, in Morehouse's comet we have its photographic history from the very beginning; if you look back a few pages you will see that this was one of the comets which was discovered by photography, and astronomers followed it with much care to find out what would happen as it drew near the sun. Most extraordinary changes took place in it. Great, irregular masses of light were apparently thrown out from the head and traveled out along the tail, and at one time the tail itself even seemed to break away from the head. The tail became twisted, as if a great cyclone were whirling it about. At one time the newspapers were full of the story that the comet had lost its tail, and from the photographs we can see just when this happened.

On September 29, the tail was quite normal. On September 30, it showed signs of great activity, and the neck which joined it to the head became very narrow and tapering. The astronomer watched its wonderful changes during this night as long as he could. On the following night the bright bunch of light had moved many thousands of miles away from the head, and a new tail which was just beginning to form was seen quite faintly. The separated part traveled farther and farther from the comet, and finally faded out. Two weeks later the new tail became strangely twisted and it was not until a month later that the twists became straightened out. And six weeks later, the second tail presented a very irregular appearance; there were fine bright streamers stretching out from it, while from the head of the comet there was seen the beginning of still a third tail.

These very interesting photographs showed clearly how wonderfully great the changes are that are taking place in the tails of comets. They prove to us as surely as it can be proved that the material of which the tail is composed is of a very filmy nature, for if it were not it could not possibly undergo such very violent changes in such short periods of time.

HOW PLANETS CAN CAPTURE COMETS.

We have already seen how comet material which is traveling slowly along in space may be gradually but firmly pulled into our system by the attractive power of the sun, and how it sweeps around the sun in an enormous parabola and then goes away again into space. But sometimes it happens that the comet in its journey passes quite near to some one of the planets, perhaps so near that the pull of the planet on it is nearly as strong as the pull of the sun. Although even then the planet cannot pull it enough to make it move around itself instead of around the sun, yet it may so change the comet's path that ever afterward it will pass around the sun in an elliptic path instead of in a parabola. And as the ellipse is a closed curve, the comet will ever after remain in our system.

Some of the planets have captured many comets in this way, and added them to the family of worlds which move around our sun. If several comets have been captured at different times by the same planet, they are called that planet's "comet family." Neptune has six members in its family, the most interesting one of which is Halley's comet. Uranus has two, and Saturn one, but Jupiter, which is the largest planet of all, has as many as thirty. The comets which belong to Jupiter's family move in paths so small that they pass completely around the sun in from three to eight years, and many of these comets have made several re-appearances since their original discovery. Some of them are very interesting, especially one known as Encke's comet which moves around the sun more quickly than any other comet known. From the way in which this little comet moves we know that somewhere in its path it draws near to some unknown body or to some meteoric cloud which disturbs it in its motion, but what this disturbing thing may be we do not know: no man has ever seen it.

Sometimes it happens that a planet will reverse its effect on a comet. That is, after having pulled it away from a parabola and turned it into an elliptic path, around which it journeys several times, the comet may come into such a position with reference to the planet that the planet may pull it back into a parabola again. If this happens, the comet will travel along its new route until it is entirely out of the solar system. Lexell's comet is thought by some astronomers to have had this experience. This comet was discovered in 1770 and was found to be moving around an elliptic path in five years. As it was unusually bright it would surely have been seen on its return, but it has never been recognized since though its motions have been studied with very great care. It is now believed that it passed so near to Jupiter that its path was changed into a parabola, and that it left our system never to return. This little body is known as the "Lost Comet."

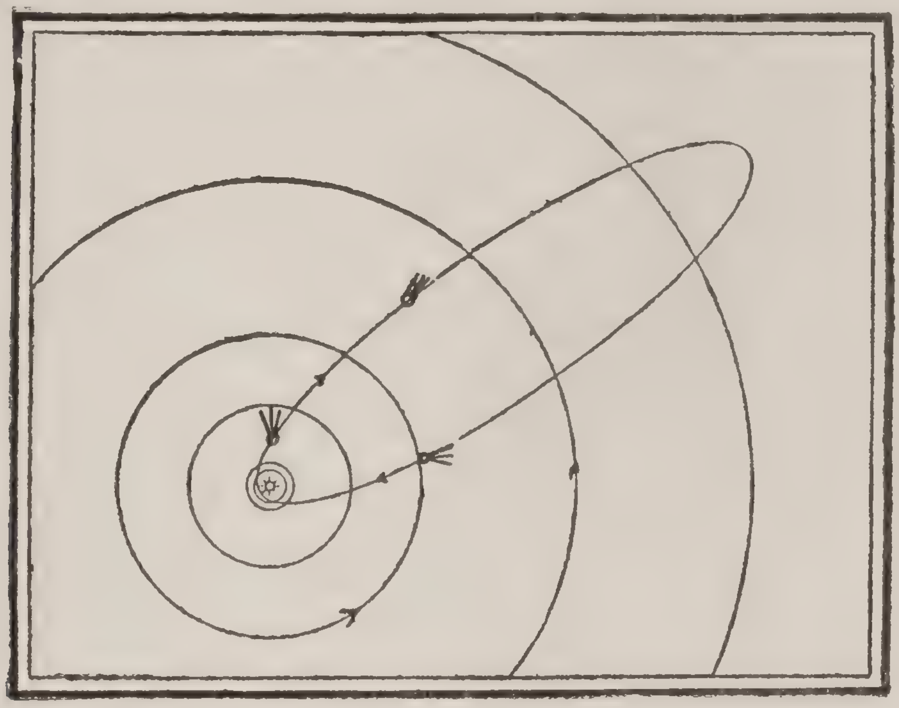
HALLEY'S COMET.

We now come to the story of Halley's comet, which is perhaps the most interesting of all. All readers will remember how brightly it shone in the early morning sky during the spring of 1910, and how it was predicted that the earth would pass through its tail. The newspapers, too, were full of it; hotel keepers took advantage of the popular interest to have all-night comet parties, and on the night when the passage through the tail was expected, the interest was intense.

Its history begins more than two centuries ago with the English astronomer Edmund Halley, for whom it is named though he did not discover it. Halley was a friend of Sir Isaac Newton, whose laws of gravitation we have already told about. These laws were used by Newton to explain the motions of the moon and planets, but Halley thought that they might also show how it is that the comets move. Selecting the bright comet of 1682, he studied its motion with the aid of the new laws, and discovered that it moved in an elliptic path and that it passed entirely around the sun in the course of seventy-five years. Looking back over the old records, he found that a very large comet had been carefully observed in 1607 by the renowned Kepler, and that in the year 1531 another bright one had been seen. By studying their paths as well as he could from the rather rough observations (for that was before the invention of the telescope), he decided that these three comets were the same one, and that it would appear again in the year 1758.

Halley knew that he himself could not expect to live until his comet should be seen again, but he hoped that astronomers would carefully watch for it, and he said: "If it should return according to our prediction about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman." And posterity has not forgotten it, even now, more than two hundred years afterward, for the history of Halley was told in all the popular magazines during its recent appearance, and the general interest in comets was very great.

As the year 1758 approached, astronomers were eagerly watching the heavens for its first appearance. It was first seen on Dec. 25, by a German landowner who had a small telescope, but who was only an amateur astronomer. Later it developed a long and brilliant tail, and was seen by everyone. Its next return was predicted to take place in 1835, and now astronomers were able to tell of its motion with much greater exactness than before, because the observations of it made in 1758 were very accurate ones, and because the laws of motion were by this time much better understood. It was known that every time the comet passed near a planet, the planet gave it a little pull, thus pulling it slightly out of its path. These pulls are called Perturbations, and in predicting what its position in the sky would be when it returned all of these perturbations had to be calculated. This was a very large problem and took the astronomers a long time to work out, but when it was done it enabled them to find the comet quite close to the predicted place. At its return this time it had a long and beautiful tail, and many accurate observations were made of it.



The Path along which Halley's Comet moves about the Sun. The smallest circle shows the Path of the Earth; the largest one shows the Path of Neptune.

WHAT WAS SEEN IN 1910.

The expected return in 1910 naturally created great interest. A prize was offered for the best determination of the path, taking into account all the perturbations since 1835, and this was won by two Englishmen working together. Its early history was examined, and many records of it were found, among the most interesting of which was the account of it when it was seen in the year 1066. This was when William of Normandy was planning to invade England, and the appearance of the comet greatly terrified the unfortunate Saxons. The success of the Norman invasion and the death of King Harold were said to be due to its injurious influences. Many other references to the earlier appearances of the comet have been found, not only in European records, but also among the Chinese, who were very exact observers.

After the positions which the comet would occupy among the stars at its recent appearance had been published, astronomers began to hunt for it, some with their large telescopes and some by means of photographs. The first to find it was Professor Wolf, of Heidelberg, Germany, who found it on a photograph taken on September 11, 1909, very nearly in its predicted place. Word was at once sent all over the world, and in a few nights Professor Barnard, using the great 40-inch telescope of the Yerkes observatory, saw it with the eye. When first seen it was about as bright as a seventeenth magnitude star. It grew brighter very slowly as it approached the sun, but it could hardly be seen without a telescope until it had passed around that body and entered the morning sky. It reached perihelion on April 20, 1910.

By this time, astronomers were looking ahead to see how near it would come to the earth, and they found that on May 18, it would pass directly between the earth and the sun at a distance of only fifteen million miles from us. Beside this, it would be so nearly in line with the earth and sun that it would probably be seen to pass over the face of the sun, as did the comet of 1882. And at this time its tail, which stretches directly away from the sun, would probably be so long that the earth would pass through it, as it passed through the tail of the comet of 1861.

This last prediction caused great excitement throughout the astronomical world, and preparations were made for many kinds of observations. The passage of the head across the sun was to take place after the sun had set in the eastern part of the United States, hence in order to observe it best an expedition was sent to the Sandwich Islands. It was calculated that the earth would pass through the tail after midnight on May 18. Unfortunately for the best observations, the moon was past the first quarter and its light greatly diminished the brightness of the comet. It was expected that the best views of the tail would be seen in the mornings just before May 18, and in the evenings for several days afterwards. These were the expectations: let us now hear what was actually seen.

In the first place, the comet's tail lay rather close to the ground, instead of standing upright in the sky, in which respect it was like the comet in 1843. On May 5 the tail was one-ninth as long as the distance across the sky; on the 13th it was one-third as long, and on the morning of May 18, it stretched more than half way across the whole heavens. The head was rather faint and somewhat reddish in color, being about as bright as the stars in the Great Square of Pegasus. It rose shortly before dawn, some time after the tail was well up, so that the conditions for observing it were not very good.

The night of the 18th, when we were to pass through the tail, arrived, and on this night there was bright moonlight. Somewhat unusual electrical phenomena were seen at various places, and at others a faint glow was noticed in the northern sky, but there was nothing very remarkable in the heavens. Toward two or three o'clock in the morning, when the moon was nearly setting, a tail of the comet was seen in the east, which reached fully two-thirds of the way across the sky. Underneath it the sky was quite dark, and nearer the ground there was another bright streamer, a little fainter than the first. This was a most unexpected and puzzling sight; and to the amazement of astronomers, on the next morning at the same time, the light streaks were again seen in the east, while in the west the comet's head shone out without any tail at all. Later a tail developed, but it was quite inferior in length and brightness to the one seen in the east. What had happened? Unfortunately we do not certainly know. Some think that we really passed through the principal part of the tail at the predicted time, and that the lights afterward seen in the east were merely streamers. Others think that the tail bent eastward and that we really passed through it a few nights later, while still others believe that the tail bent slightly upward at the critical time and that the earth passed wholly below it. We have seen by our study of Morehouse's comet how very strangely the tails of comets may act, and how suddenly they may change their shape and position. It is possible that something of this kind happened on the night of May 18, but we do not know that it did.

The observers in Honolulu who were watching to see the comet pass over the face of the sun, saw absolutely nothing. A very interesting report was received from observers in the southern hemisphere, where the tail stretched high up in the sky and was seen much better than here. Two branches to the tail were seen very distinctly, but, very curiously, the tail grew narrower toward the end instead of spreading out in a fan-shape. Later the comet gradually faded away, as it drew away from the earth; its tail disappeared, and at last it became again the little nebulous cloud that it was when first seen.

Thus Halley's comet has again come and gone. We gained much knowledge from it, but it presented many puzzling questions. The great exactness with which it followed its predicted path is a striking evidence of the truth of the laws of gravitation and of motion. But the strange behavior of the tail shows us that we still have a great deal to learn on that subject. All that astronomers can do is to wait patiently until another great comet arrives through whose tail we shall make a passage. Meantime we have said good-by to Halley's comet for another seventy-five years, hoping that when it returns next time we shall be better able to unravel its mysteries.

CHAPTER XX.

Visitors to Our Solar System—Shooting Stars and Falling Stones.

HOW TO SEE A SHOOTING STAR.

IF, on a clear, moonless evening you place yourself in some retired corner out of doors, where there in no electric light and no gas light to tire your eyes, and look up into the sky, only a few minutes will pass before you see a little ball of fire dart through the sky, like a rocket, perhaps leaving a trail of sparks behind it. If you keep on watching, you are sure to see several others. We call them Shooting Stars, or Meteors. Some move very swiftly, and some rather slowly; with some, the trail lasts several seconds, but with others it vanishes at once; and some are very much brighter than the others. You do not know just where to look for them, but if several of you are in the party watching, first one and then another will call out that a meteor has been seen.

Occasionally, when looking through the telescope, the astronomer may see a speck of light dart across the field. This is a telescopic meteor. Sometimes the trail of a meteor is found on a photographic plate and by looking at this we can see how the meteor grows brighter and fainter as it moves over the sky.

WHAT A SHOOTING STAR IS.

Some people think when they see a meteor, that a star has really fallen out of the heavens, but this is, of course, not true. We know that the stars are great suns, almost infinitely far away from our earth, and although they are swiftly moving yet because they are so very far away we could not see that they had changed their places in the sky even if we should watch them for many years. But meteors are very much nearer to us than the stars are, in fact they are not more than one hundred miles from us when we first see them; that is, they are in the extreme upper part of our atmosphere. They are particles of solid matter, of different sizes, but mostly quite small, which are moving quite swiftly about, everywhere in space, both in inter-stellar space and in our own solar system. The great star cloud is filled with these little particles and it will be remembered that we think a comet is very little more than a cloud of these little particles crowded together.

Whenever a little particle comes near the earth. it will be drawn toward it by our earth's gravity; it falls toward the ground faster and faster just as any other little stone would do, until at last at the end of its long fall of many thousands of miles it will be moving nearly seven miles a second. But each little particle, as it falls toward us from outer space, is also kept moving faster and faster by the pull of our great sun. And beside this our earth is rushing around the sun faster than eighteen miles each second. It may therefore happen that the earth and the little particle run into each other at a very high speed indeed. Some meteors have been seen to move across the surface of the earth faster than forty miles in a single second.

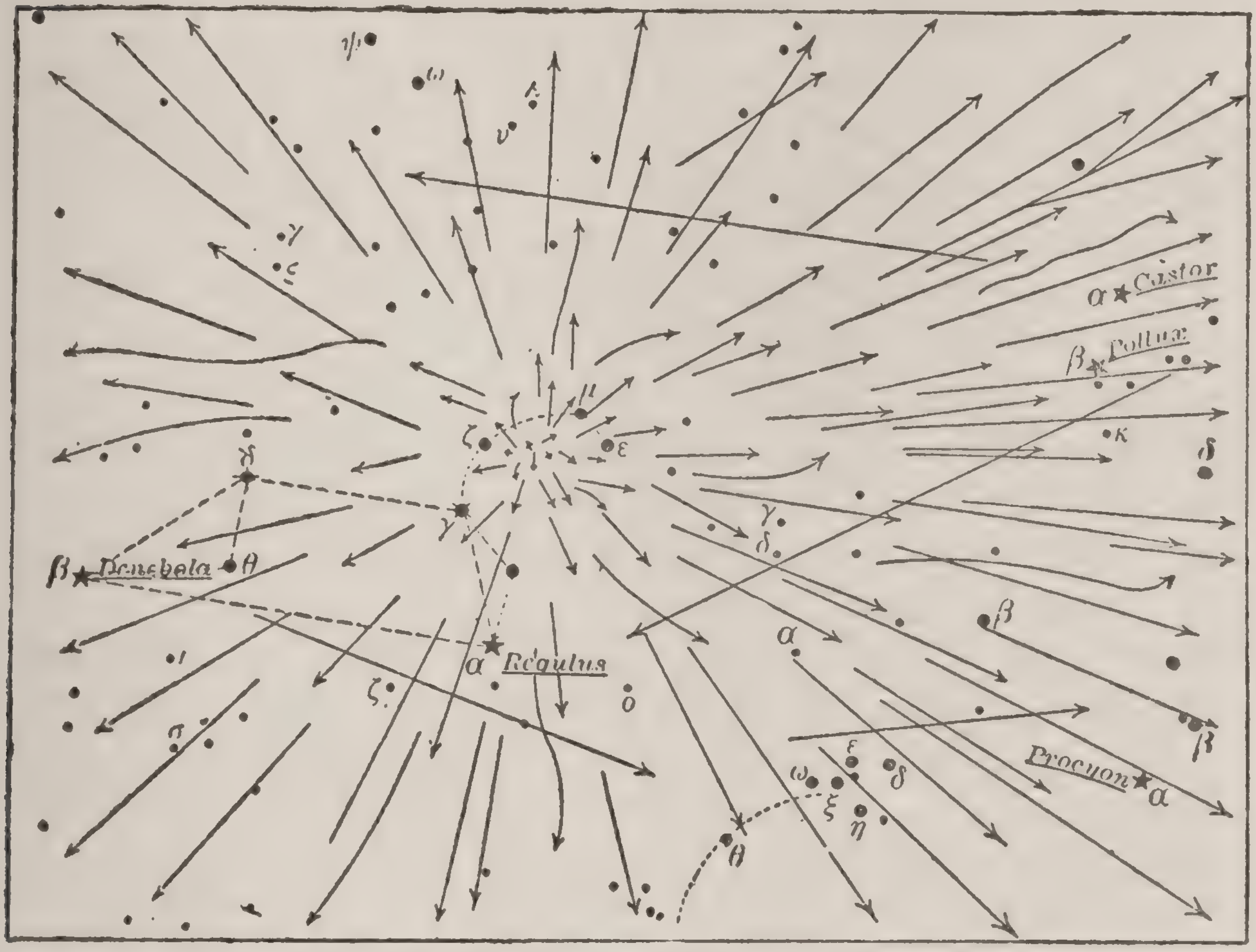
All around our earth there is an ocean of air, which is almost one hundred miles deep. As the swiftly moving little particle ploughs through this air it is held back more and more until, if it at last reaches the ground, it may be moving very slowly. In Russia some falling stones once fell on the ice among a party of skaters and they fell so gently that they did not even break the ice. Usually, however, a falling stone strikes the earth so very hard that it is buried deep in the ground.

But very many of the little particles never reach the ground at all. As they plough through mile after mile of air they get hotter and hotter and at last, if the particle is a small one, it gets entirely burnt up. It gets burned into the train of heated and luminous gas which we see left behind it, and this soon cools off and then all that is left of the particle is some very fine dust which finally falls slowly to the surface of the earth. We may find this fine dust in several different places. We must look for it where it can collect undisturbed by winds which blow it about, or by creatures, human or otherwise, which will trample it into the dirt. Such a place is on the surface of the Arctic snows or on the snow which covers the tops of the mountains: there the meteoric dust is always very slowly settling and there it may be found.

One observer collected a great mass of snow, and when he melted it, he found a great many small, round bits of certain minerals, particularly iron, in the water, and these were all that was left of many shooting stars. Other scientists who study the bed of the ocean by dredging sand and other matter from the bottom, find just the same little particles of dust there. Another observer tells how she placed a piece of white cloth in a protected spot, and in the course of several hours, found small black specks on it, which, when examined with a microscope, proved to be the same kind of meteoric dust. Thus we see that the ''ashes'' of meteors fall gently to the earth as dust. In the course of a year the earth runs into many hundreds of millions of meteors. It is thought that in this way it gathers up about fifty thousand tons of meteor dust each year, but our earth is so very large that even if so much dust as this is always falling on it, it will be eight hundred million years before enough has fallen to cover it with a layer only one inch in thickness.

SHOOTING STAR SHOWERS.

While it is true that you can see a number of shooting stars every evening when you look for them, there are times when they are so numerous that they make a shower. Every August, from the 9th to the 11th, fifty or a hundred can be counted in a very short time, and they are usually quite bright with long trails.



The Shooting Stars seen on November 13, 1866, showing how they seemed to move outward in all directions from a little region in the sky called a Radiant.

These are called Perseids, because if we could follow back their paths we should find that they all started from the group of stars called Perseus. The point from which they seem to come is called the Radiant, because the meteors seem to radiate from that point. This is not the only shower, but it is one of the largest of those that come every year. At least one hundred others are known; some do not come every year but at certain longer intervals. Of these, two are particularly interesting: the shower of the Leonids, which is seen in November once every thirty-three years, and the Andromids, which occur also in November, but later in the month and at intervals of either six or thirteen years. The first is interesting because it is so large, and the second because it is connected with the history of a certain comet.

THE NOVEMBER SHOWER OF SHOOTING STARS.

The Leonid shower is seen in November from the 12th to the 15th of the month; this shower is brightest once in thirty-three years: it was seen in 1799, 1833, 1866, and every thirty-third year after these times. It was expected that it would be seen in the year 1899, but we shall soon see that the shower of this year has a special story connected with it. As we go still farther back in history, we find references to this shower, not only by astronomers, but by historians and writers of all sorts, for such an extraordinary event could not escape the notice of every one. An American astronomer at Yale University, investigated the history of this shower and found many descriptions of it as far back as the year 902 A.D., which was known as "the year of the stars." An Arab historian, in writing of the shower of 1202, says: "The stars shot hither and thither, and flew against one another like a swarm of locusts. . . . People were thrown into consternation and made importunate supplications to God."

The appearance in 1833 was the most remarkable one of recent years; it was best seen by observers in America. At one place, the number that were seen to fall in five or six hours was about two hundred thousand. They were as numerous in the sky as snowflakes in a heavy snow storm. There had also been a small shower the year before, and during the two following years at the same time an unusual number was seen. In 1866, just thirty-three years afterward, another remarkable shower occurred, and another less striking shower was seen in the following year.

STRUCTURE OF A SHOOTING STAR SHOWER.

From the study of all these facts, astronomers have come to the conclusion that this meteoric shower consists of a great stream of small particles traveling around the sun in a long, elliptic path like that of a periodic comet; that this path crosses the path of the earth at the place where the earth is in November, and that the densest part of the stream passes around its long path in thirty-three and one-third years. This swarm of particles is much like a comet swarm, but it is not nearly so compact. In the shooting star stream the particles are scattered far apart; they are not arranged in any regular, even order, but are probably much thicker in the middle of the stream, and there are widely scattered ones in front and behind.

The swarm of particles may be compared to a large crowd of children when school is dismissed. Suppose that you are standing at a window in a house near the school at twelve o'clock. First you see a few boys running down the street, then a group walking fast, then more, then the great mass of children, then a fewer number, then half a dozen or so, and at last two or three who had to stop after school a moment. If, instead of standing in the window, you are walking along a cross street you will meet some of the pupils and the number you meet will depend upon the time you reach the crossing.

So it is with a swarm of meteors. They go along their own path like the children who are passing down the street, and when you meet them, you are like the earth in its path which crosses the path of the swarm, once each year. The children that you meet would be the meteors which come into our atmosphere. If you go early, you meet only a few, but if you are five minutes later, you pass through the thickest part of the crowd; if you take the same walk the next day at the same time you will meet the swarm of children again.

Let us put this explanation into more scientific language. We have found the path of the Leonid swarm and that the earth's path meets it in a certain point which is reached by the earth in November. The earth reaches this spot every year, but as the meteors spend thirty-three years in moving around their path we do not meet them every year, but only three times in a century. However, this swarm is not quite like the group of children hurrying home from school, but rather like a long procession, and the earth has time to go round its orbit more than once, before the procession has passed the meeting point. It does not take long to go through the thickest part of the shower, but there may be small showers a year or even two years before or after the great shower.

What happened to the shower of 1899 we do not know. Astronomers began to look for it as early as 1896; each year they saw a number of large meteors at the proper time, but they were very much disappointed not to get a really magnificent display like the one of 1833. It is almost certain that the pull of some one of the planets drew it out of its course so that the earth no longer meets it. If so, we hope that before 1932 it will be drawn back again, but astronomers do not think that is likely to occur. They fear that we have lost sight of the magnificent Leonid shower forever.

A swarm of meteors is therefore very much like the head of a comet, only the particles of a swarm are very much more scattered than those of a comet. We even know that the material which goes to make up a comet may be so scattered by the attractive forces which act upon it that it no longer appears as a comet but is drawn out into a long stream, and if the earth happens to rush into this stream we will see a meteoric shower. We have actually seen a comet broken up in this way. After this happened, the earth passed through the remains of the comet and a shower of shooting stars occurred.

HOW A COMET WAS BROKEN UP, AND WHAT BECAME OF IT.

In the year 1821 a small comet was discovered by an Austrian officer named Biela, and it was found to be moving around the sun once every seven years. Toward the end of 1843 it was seen again, during November and December, and a month later astronomers were very much astonished to see that it had separated into two parts; it had changed into two entirely different comets which traveled along together. Such a thing had never happened before, and to the increased astonishment of astronomers, in March the second part entirely disappeared, though the other part was seen for a month longer. The comet was expected to return in 1852, and its appearance was watched for with great eagerness. Again it was divided and the parts were much farther apart than they were before. This continued until their disappearance in September.

The next two returns were not favorable for observation, as the earth was not in a good position, but the return of 1872 was awaited with much eagerness. If, according to the theory, the comet had already begun to break up into two parts then, naturally, this process would continue; the matter composing it would be distributed along its path, and as it happened very fortunately that the earth crosses this path later in November, and we should run into a meteoric shower at that time. This prediction was verified, for at the exact time when the earth was crossing the path of the comet, a fine shower of shooting stars was observed. These seemed to come from the star group of Andromeda, and hence these shooting stars are known by the name of Andromids. The shower was not as wonderful as the Leonid shower of 1866, but it was far larger than most showers and attracted a great deal of attention, even from those who knew but little about astronomy. A second return of this shower was expected in 1885, and again the prediction was verified; a striking display was seen in which the meteors were even finer and more numerous than in 1872.

This intimate connection between Biela's comet and the Andromids tells us clearly that a meteoric shower is the remains of a comet which has been broken up and scattered along its path by the force of the sun. If the particles which compose it are still close together we have a great shower whenever the earth passes through the dense cloud, but if they are pretty well scattered along the entire path we have a number of meteors every year. There may also be a difference in the size of the original group. The group which made up the November shower must have been a very large one, and we also think that it has been in our system very long, because we know that the longer the force of the sun acts upon it the more evenly the particles become scattered. As therefore the Leonid meteors are in one quite compact group we are sure that they have not been in our solar system for a very long time. It has, in fact, been calculated that this group was captured by the planet Uranus in the year 126 A.D. The Perseids, on the other hand, must have been here a long time, since they are scattered to such an immense distance along their path that we have a shower from them every year.

METEORITES OR FALLING STONES.

Sometimes these flying masses of stone or iron, instead of being entirely burned up in our atmosphere fall to the earth; we then call them meteorites or meteoric stones. They usually strike our ground so hard that they are found buried in the earth. It is not often that a meteorite is seen to fall, but when this happens there is a sound like the rushing of a heavy train and often explosions louder than the loudest thunder. Sometimes sparks are seen to fly from it and sometimes its passage through the air is accompanied with brilliant flashes of light, and if it finally bursts, it does so with a loud report.

A great Meteorite found in Oregon in 1902; its large size is shown by the two children who are lying in the hollows which were burnt out of it during its passage through the air.

Some of these falling stones contain a great deal of iron, and a few of them are nearly pure iron, but most of them are hard, compact stones, made out of many different things, just as stones on the earth are. Twenty-seven different substances have been found in them, but nothing has ever been found in any meteorite which does not also occur on the earth. The interesting gas called Helium, which was found on the sun so many years before it was discovered on the earth, is also found in some meteorites, and some of them contain carbon in the form of very little diamonds.

When meteorites reach the ground we find that they are usually covered with a glossy, black crust which is full of little hollows called "Thumb marks," because they look just like a mark made in some soft substance by pressing the thumb against it. The smooth crust is formed when the stone is ploughing through our air, by the melting of the outside surface by the friction. We must remember that when a great stone strikes our air it is only the very center or core of it which can reach the ground; the rest is all melted and swept away by the enormous friction.

If a meteoric stone is melted by great heat, gases are often seen to pour out of it. These gases have been hidden away in the pores of the stone, just as water may be hidden in a sponge, and they have been carried with it on its long journey through the depths of space. And the presence of these gases is one of the most wonderful and puzzling of all the strange and puzzling things about meteorites. For they are soaked full of gases, and we know of no way in which they could have taken these up except by being heated very hot indeed at some time when the gases were around them. So we must believe that at some time of their past history they have been subjected to a great heat; this makes the explanation of where the meteorites come from very difficult.

THE MAZAPIL METEORITE.

Some of the records of the falling of meteoric stones are very interesting. A meteorite which fell in Mexico in 1885 is quite famous; this is called the Mazapil meteorite, and one who saw it fall tells the following story: He was out with his horses at nine o'clock in the evening, when he heard unusual noises and saw bright flashes of light. People were frightened, and rushed out of doors, when they found that the air was full of a strange, phosphorescent light. Looking about, they found a hole in the ground and a great hot ball lying in it, but they were afraid that it might explode and so they left it until the next morning. When they then examined it they found that it was a mass of iron weighing about nine pounds. If so small a mass as this could cause such a disturbance, what a wonderful sight must have been presented by the fall of the Bahia meteorite in Brazil which weighs no less than five and one-quarter tons. But this was not actually seen to fall.

Appearance of a falling Meteorite as seen in California on July 27, 1894.

Another falling stone has a more exciting story because several people happened to be almost in the line of its path and there was not time for them to escape. Horses and dogs were frightened, terrific explosions were heard, buildings were shaken as if by an earthquake, and finally the disturbance passed on. In the course of time about eight hundred pounds of stone were picked up which had fallen from this meteroite when it exploded. One of the pieces was found on the top of a snow bank, many of them were afterward ploughed up in the fields, while the two largest pieces of all fell by the roadside and a lawsuit was begun about them to decide whether they belonged to the person who found them or to the one on whose land they fell. It was decided that they belonged to the owner of the land.

The most thrilling account of the fall of a meteoric stone is that given by the captain of a vessel which was crossing the Atlantic. One night, as he was standing on the bridge of his ship, he suddenly saw a great ball of fire coming straight toward him. It moved with fearful swiftness, so that there was no time for him to do anything. He had no time to change the course of the ship nor even to get out of the way himself, but fortunately, instead of striking him, the ball of fire fell into the sea several yards ahead of the ship. Had it struck the vessel it would either have sunk it or set it on fire, and all on board would have perished.

WHERE METEORITES COME FROM.

What is the origin of these strange visitors which come to us from the depths of space? As yet we do not know. It is certain that they were never on the earth before, for they come into our atmosphere with such very great speed that they could not have been blown out of any earthly volcano. Some have thought that ages ago they may have been ejected from the volcanoes of the moon, and that they have been moving around the sun ever since, and have only now come into collision with the earth. But it is easily proved that this is quite impossible, for no meteorites falling upon us from the moon could meet the earth with so high a speed as many of them do. Still others have thought that they may have resulted from the breaking up of comets, but if this is so it is difficult to account for the presence of the gases with which they are sometimes filled.

Many astronomers think that meteorites come from far outside of our solar system, perhaps from some star, or, still more probably, from some one of the worlds which we believe are revolving around many of the stars, and that inter-stellar space has very many of these meteoric stones moving about in it. Professor Newton, the astronomer who first investigated the

November shower of meteors, finds that many of them move about the sun in elliptic paths. It may be that they have been captured by planets, just as comets sometimes are, or it may be that they are a part of the great nebula from which the sun and planets were formed ages ago.

If, as we hold one of these stones in our hand, it could but tell us of its journeys, what a strange story we would hear! It has come from a distance so great that when we think of it, Japan or Australia seem close at hand. It has been travelling toward us for millions of millions of years. Perhaps it began its history on some world far out in the great star cloud. For age after age it has wandered in inter-stellar space, and at last chanced to be drawn near the star we call our sun. It may have passed around and around this body for many ages more, but at last it falls upon our little world and its long wanderings are ended.

CHAPTER XXI.

Changes in the Universe.

HOW THE WHOLE UNIVERSE IS SLOWLY CHANGING.

WE have now finished what we have to tell about the multitude of wonderful objects which are around us. We have told about the millions of suns which stretch away from us in a great cloud, about the strange, wonderfully large, faintly shining clouds called nebulas, about our own little sun with the family of worlds moving around it, all placed like an island in an endless ocean of other suns, and lastly of the meteors and comets which come from unknown regions to visit us.

Not that we have told all that there is to tell. Men spend their whole lives studying only one little part of it all, and they continually find out more about it that is new and interesting. Many books larger than this one are written on double stars alone, while the volumes which tell about the wonderful things found out with the spectroscope would fill a small library. Perhaps some day you may yourself be an astronomer, and then when you have found out what part of this wonderful study is most interesting to you, you will spend nearly all your time studying what men have learned about your chosen part and in discovering new things in it yourself.

But without describing everything in it, we have at least gotten a general view of the wonderful universe of worlds. As we think of it all, we are overcome by its grandeur and inconceivable size. But more than this, we clearly see that everything, everywhere, is in a state of change. There is nothing which is, that was not once very different from what it is now, and which will not take on a still different form in the ages which are to come. We see the whole as it were for an instant, as on a dark night we might see houses and fields and moving people and steamboats revealed in a sudden flash of lightning. We as surely know that the whole heavens are changing as we know that the trees and plants which we see around us on a summer day are slowly changing too.

But suns and worlds grow old very slowly indeed. If the very first man who was born in the world could have lived until now, it is not probable that he would have lived long enough to see how most of the stars are changing. Even our own sun, which is so very near us and which we can study so much more easily than we can any of the other stars, is growing old so slowly that he would probably not notice that it looked any different at the end of his long life from how it appeared to him at the beginning.

How then do we know that the stars are surely growing old? Can we tell how they have grown, how they change, and what will some day become of them? Can we learn how they are formed and what they are formed from? In short, can we tell what the great universe was like countless ages ago, how it slowly changed until it became what it is now, and what it will change into in the far distant future?

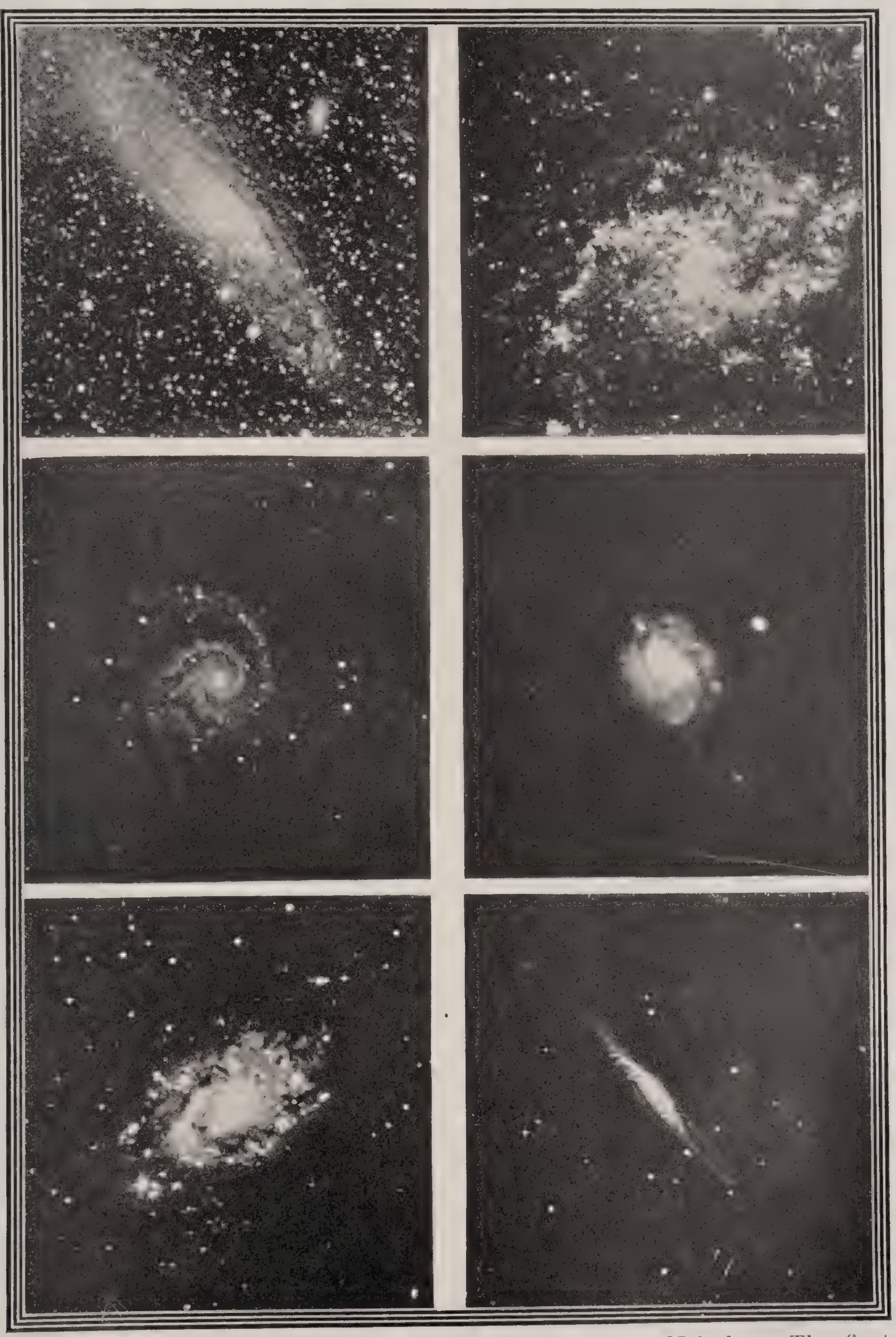
How worlds are made! It is a grand and wonderfully interesting study. There is much here that we do not know, and yet we are learning more and more, and already much has been found out. We have seen how the wonderful force called gravitation keeps all the worlds of our solar system moving around our sun, how it accounts for the motions of comets and shooting stars, and how because we knew of this force we knew certainly that the great planet Neptune existed before it was ever seen in a telescope. And from a study of double stars, we know that this wonderful force is always acting, even out to the very limits of the starry universe. Every little particle of matter in the universe is pulling on every other particle, and if we know how large and how far apart they are we can tell exactly how hard they will pull.

If we see a great nebula out in space, and if we know, as we do, that every little particle in it is pulling on every other particle, what is certain to happen to the nebula? We are sure that it will grow smaller and hotter, and that after a very long time it will become a round, hot star. But if the nebula is one of the thousands of nebulas in the sky which are of a spiral shape, we believe that it will change into a sun which has worlds moving around it. And so we believe that our own sun with its whole family of worlds was once nothing but a great spiral nebula.

The study of the way in which worlds and suns were formed is the most important and profound part of all astronomy. But it is a study which is very difficult. Although we have found out much, there is much of which we are not certain, and still more of which we know nothing at all. In the following chapter of this book we will give fully and clearly an exact statement of what we have learned so far, and especially of how our earth was formed and what we know of its past and future history. Important as this chapter is, for it contains an account of the latest and most profound researches of astronomers, the reader would at first probably find it very hard to understand. To make it clear to him, we devote this preliminary chapter to telling of the changes which are now taking place in our universe, and of the important things we must know about matter, heat, and energy before we can clearly understand what men have learned about the growth of worlds.

TWO REMARKABLE NEBULAS.

In the star group known as the Hunting Dogs, there is a little misty spot of light, just south-west of the



Photographs of six of the wonderful clouds called Nebulas. The first of these is the Great Nebula in Andromeda.

little star in the end of the handle of the Great Dipper. When this is viewed with a telescope it is seen to be one of the most wonderful objects in the heavens. It is the great Whirlpool Nebula, a wonderfully large, faintly shining cloud, in the middle of which is a bright, oval mass, and around this the arms of a great spiral are wrapped ever more and more closely, exactly as we see streams of water wind around the center of a whirlpool.

In this wonderful nebula there are two great arms, one of which ends in a bright cloud of nebulous matter; and the whole is extraordinarily irregular, filled with great knots and dense clouds, and with many smaller arms or streams, all coiled around the cloud in the center.

As we look at this wonderful object, doubtless many thousands of times larger than our whole solar system, we feel we are looking at matter in terribly swift motion, very much like clouds of dust which on our earth are sometimes swept around by a whirlwind. But in this we are mistaken. This nebulous cloud is not like a whirlwind at all; its particles are not being swept around the center along the spiral streams, but each particle is moving around the center in its own path, and the arms of the spiral only show us where the particles are crowded most densely together.

In the star group called Andromeda, there is another great nebula, so large that the distance across it is more than thirty thousand times as great as the distance from the earth to the sun. In this cloud, which is so bright that it can be seen without any telescope at all, the greater part of all the material has by this time become part of the bright cloud in the center. But around this cloud there are seen very large, faint spiral streams separated from one another by black lanes, while outside of the whole there is a much smaller cloud which seems to have been left behind by the larger nebula as it shrank together. In the same way in the ages to come the smaller cloud of the Whirlpool Nebula will probably be seen entirely separated from the central mass.

BEFORE OUR EARTH WAS BORN.

Wonderfully large as these great clouds are, it is thought that ages ago they were much larger still. What the enormous clouds were made of we do not know. Probably they were formed of a great many solid particles like the meteorites which sometimes fall on the earth, and with these there were probably an innumerable number of particles so small that they were nothing but a fine dust. Mixed up with the solid matter there were very likely a great many little molecules or even ions of different gases, and all these things together formed a wonderfully large, light cloud.

Whatever the great cloud was made of, we are perfectly sure that every little particle in it must have been pulling on every other particle, because between every piece of matter in the universe, no matter how small, the force of gravitation is always acting. And we know that all these pulls would make the nebula shrink together. The central part would grow ever denser, and at the same time many smaller knots or clouds would be formed by the drawing of the material together at other places.

At last so much material would have been gathered into the center that its pull would begin to govern the motions, not only of the smaller knots and clouds, but of every particle of matter in the whole nebula, just as the pull of our great sun keeps not only all the planets, but also each of the little asteroids moving around it. None of the knots or particles move along the spiral streams which we see; each is moving slowly around the central mass, and the streams show us only where many particles are crowded together. In much the same way, if you hold a stake in swiftly running water you may see ripples spreading out from the stake where the water is heaped up, but the little particles of water do not move along the ripples.

And so, at last, by gravitation alone the form of the nebula will have been changed, until it has become a dense, central cloud around which many other clouds are moving. But not all the matter of the nebula is yet gathered into the denser clouds. The whole region is still full of nebulous matter, and each smaller cloud in its journey around the center has to plough its way through this matter. This, as we shall see in the next chapter, makes some very important things happen. We shall see that it changes the little clouds into turning worlds, which move in round paths about the sun, just as we see that the planets do.

At this point we may stop to ask, how in the beginning was the spiral nebula itself formed? Would a great, irregular cloud have the form of a spiral at one stage of its shrinking together under its own gravity, or must we try to explain the strange shape in some other way? We are not certain: some think that the spiral form may arise from shrinking alone, and this seems very probable. Others believe that a spiral may be made by the flowing together of two great clouds or streams of nebulous matter, which, as they meet one another, are coiled up, just as two currents of water often form a whirlpool when they flow together. And in the next chapter a suggestion is fully explained that a star may be torn apart by another star, and from this a spiral nebula may be developed.

If all that we have said is true, then all the worlds that are near our sun, and even everything that the sun itself is made of, were once spread out into a great spiral nebula. This wonderful cloud probably stretched out into space to a distance many hundreds of times as great as the distance from the sun to Neptune. Could we have looked at it then we would have seen it to be a real spiral, probably having a dense, bright, central portion, and many arms coiling around this center on which there were very many irregular knots or condensations of cloud-like material.

As the ages went on, all the little clouds moved around the center, pushing their way through the material around them, and falling ever nearer to the central mass. Cloud after cloud must in this way have fallen on the center, until at last but very few were left. Our sun is one thousand times as heavy as all of its eight worlds put together; in the early ages it swallowed up all the rest of the material of the great spiral cloud.

At last the time came when the nebula did not look like a spiral any more. It was very much smaller than it had been before: at its center there was a great, bright mass, and all around this the material had been swept away by the worlds which had gathered it up and then fallen onto the center. There were left eight bright little clouds; four of them, which were afterwards to become the four earth-like planets, were very near the center, and four much larger ones were farther away. All of these clouds had once been far out, near the edge of the spiral; for ages they had ploughed through nebulous material and so had been drawn nearer and nearer the sun, and now they are only saved from falling into that body by finding themselves in a region which has been cleared away by the many worlds which were nearer the sun than they were. For it is the resistance of the nebulous material which makes the bodies fall toward the sun; when no material is there they keep forever moving about that body without drawing nearer to it, just as the earth and other planets are doing now.

And so in this early age, our earth and all the other planets were great, bright clouds, all moving in round paths around a cloud far greater than them all; and this greatest cloud a very long time afterward became our sun. For, as we will soon explain more fully, each cloud must ever shrink together and grow hotter and hotter, until it becomes a round, hot body like our sun. And when at last it has shrunk so much that it must begin to become solid, it will very quickly cool again. And during the many ages while it is cooling, it may remain a warm, pleasant world on which beings like ourselves may live.

WHY WE BELIEVE THAT THERE ARE WORLDS LIKE OURS AMONG THE STARS.

There are many other kinds of nebulas in the sky beside spiral nebulas. Some, called Planetary Nebulas, are merely little round, faint objects, often having a bright, star-like point in their center, while others, called Stellar Nebulas, are still smaller and brighter and look like diffuse or cloudy stars. Beside these there are the great irregular nebulas, like the Great Nebula of Orion, and there are wonderfully large, faint streams or clouds of nebulous matter like the Ribbon Nebula and the nebulas in the Pleiades. And lastly we have the so-called Ring Nebulas, in which the bright matter is arranged in the form of a ring about a darker, central portion. But the spiral nebulas are far more in number than all the other kinds put together; it is probable that there are more than one hundred thousand spiral nebulas in the sky.

The planetary and stellar nebulas seem to have advanced so far in their life history that they have become almost changed into stars. It is possible that they are the remains of nebulous clouds which have shrunk together so evenly that all of their material has gone into the one central mass, but we cannot be sure of this. Perhaps if we could see them more clearly, we might find that even these nebulas have a spiral structure, or perhaps they were spirals once and now we can only see the great central cloud; the smaller clouds may be too small and the whole nebula may be too far away for us to see them.

As to the large, irregular nebulas, it does not seem possible that any of these can ever be gathered together into a single sun-system; in time they may form star clusters, but we do not know what they will do. And lastly, there are the Ring Nebulas, and the wonderfully large, faint streams of nebulous matter, and about these we know almost nothing. Many astronomers think that the very faint nebulous light seen in the Pleiades comes from material which has been, and is probably even now being, driven off from these stars. Others believe that it is a very fine part that is left of a great, irregular, nebulous cloud out of which the stars of the Pleiades were formed.

But whatever these strange and wonderful clouds are, and whatever will some day be formed from them, they are far less in number than the nebulas of a spiral form: there are more of these latter than of all other nebulas in the sky. Now we are quite certain that unless there are strange forces acting in these spiral nebulas of which we know nothing, and this is most unlikely, each one of them must surely shrink together under its own gravitation, and from nearly every one a central sun having worlds around it must be formed. Once in a great while the first form of the spiral might be such that every little cloud would be swallowed up by the central cloud, and then the nebula would become changed into one single star, but this could not often happen.

Long ago we learned that every star is a great, hot sun like our own. And now we learn the wonderful fact that many, and perhaps nearly all, of these stars almost certainly have worlds moving around them, just as our sun has. What a wonderful thought this is! Thousands, perhaps millions, of worlds out in the great star cloud, each forever moving around its own central sun! How many worlds like our own may there not be—how many larger ones; how many which, like Jupiter, have grown more slowly, and how many which have already passed through their life history and are now dead.

If we could travel from star to star, what strange and wonderful forms of life we would find. For it it surely most unlikely that among the hundreds of millions of suns our own sun is the only one upon whose worlds there are living creatures. On some of these distant worlds there may be beings much like ourselves; on many of them there may be creatures who are far more perfect and more wise than we are. Perhaps they have known and have studied our little world for ages, but we cannot see theirs. For if there was a world like our own, but one thousand times larger, moving around the star which is nearest to us, the very largest telescope which we have yet learned to build would be quite too small to show it to us.

WHAT HEAT IS.

Our spiral nebula whose life history we are telling has now changed into many separate, bright, little clouds all moving around a much larger cloud in the center. Each little cloud will next shrink together into a bright, hot, star-like little body, and at last will become a cold, dark world. And all the time that the worlds are forming, the great central cloud will be shrinking together too, but this will grow to be very much hotter than any of the worlds around it. And the smaller it grows the hotter it will become: long after the little worlds have become solid and cold it will keep pouring out its light and heat upon them, keeping them for ages warm and pleasant worlds. How can a sun keep growing hotter as it grows older, and how can it keep pouring out its heat for ages without burning up? To explain this we must tell what it is that causes the heat of the sun.

For a long time men have known that no matter can ever be destroyed; that is, that there is nothing which exists that can ever cease to be. If we burn anything up it may seem to us that we have destroyed it, but we have not really done so. We have only changed it into various gases which we can not see and into ashes, and if we carefully collect the ashes and the gas into which it has been turned and weigh them, we will find that altogether they weigh just as much as the thing itself did. We have not destroyed the matter out of which the thing was made by burning it; we have only changed it into a new form. In the whole universe there is exactly as much matter now as there always was; the arrangement and condition of the matter can be changed, but its amount can never be increased or diminished.

Every little piece of a single substance seems to us to be solid and of a uniform nature, but really it is very far from being so. It is believed that all matter is a swarm of an immense number of wonderfully small particles called Molecules, which are always moving among each other, but which never touch each other. To show how wonderfully small molecules are and how very many of them there are in even the smallest piece of matter, it has been found that if a single drop of water could be made as large as our whole earth, then in every cubic foot of it we would see about thirty molecules. And when the drop was so greatly increased in size each separate molecule would become about as large as a tennis ball.

We have seen that light is caused by little waves which travel through the great ocean of ether. In just the same way every warm or hot body is always sending out waves in the ether too, but these heat waves are longer than light waves. All the molecules of a body are always moving; when the body is made hotter, its molecules move back and forth faster, and it is this very fast motion of the molecules which sends the heat waves traveling out from the body in every direction through the ether. As the body is heated its molecules are set to moving more rapidly and so they push apart from each other and the body swells in size. If we heat it enough, they may even fly entirely away from one another, and then we say that the solid body has been turned into a gas. But if the body is made colder, the molecules will move more and more slowly, until at last, if it is cooled to about four hundred and sixty degrees below zero, they will entirely come to rest. This very low temperature is called the Absolute Zero. It is what a thermometer would show if it were put out in a space where there was no source of heat at all. As the stars and sun are always shining, even the empty spaces of our great star cloud are not quite so cold as absolute zero.

WHAT ENERGY IS; AND A WONDERFUL LAW ABOUT IT.

If a large ball were moving through the air and you wished to stop it you would have to put forth a certain effort to bring it to rest. And the heavier the ball was or the faster it was moving the more work you would have to do to stop it. It can be proved that it must have taken just as much work to set the ball in motion as you had to use in stopping it. The work stored up in a body in this way is called Energy. Just as men found that the entire amount of matter in the universe can never be increased or diminished, so they have found a much more wonderful thing—and this is that the whole amount of energy in the universe will forever remain the same. What does this mean? It may at first be a little hard to understand, but we will try to make it clear, and it will be found that this wonderful discovery will help us very much in learning what the future life of our sun and the stars will be.

Suppose that a blacksmith strikes an anvil with his hammer. The hammer may have been moving very fast and he may have exerted much effort in striking the blow; that is, there is much energy stored up in the moving hammer and much work would have to be done to stop it. Yet as soon as it strikes the anvil it comes to rest. What has become of the stored up energy? The answer to this question is that the energy has been moved to the little molecules of the anvil and of the hammer; the hammer has come to rest, but its motion has been given to the molecules, and after the blow they are moving faster than they were before. We would find that the anvil and hammer were both made warmer by the blow. And the warmer iron would send its heat waves out through the ether; so the energy which the blacksmith put into the hammer has all gone to send a great many waves travelling out through the great ocean of ether.

It is a very wonderful thing that work can in this way be changed into heat. And it can be shown that the same amount of work will always make exactly the same amount of heat. If you carry a ten-pound weight up a height of seventy-seven feet, the work that you do will be just enough to make one pound of water one degree warmer. In many machines the heat stored up in bodies is again used to do work: we can change energy into heat or we can change heat into energy, but the amounts of these always exactly balance. The total amount of energy never gets any more or any less.

We have already seen how meteors which are moving many miles a second sometimes strike our earth, and how they are burned up as they rush through the air. All their energy of motion is changed to heat, and this is used in making our whole earth and the air around it a very little warmer. To make clearer the very important discovery of how the whole amount of energy in the universe remains always the same, we will give another illustration of it, and this illustration will be of especial use when we come to tell about our sun.

Let us suppose that we are winding up a clock. We wind the weight all the way up to the top of the case and in so doing we do considerable work. All this work which we have done is now stored up in the weight; if we do not start the clock it will remain there forever, or until we wish for some purpose to get out of the weight the work which is stored up in it. For example, there is exactly enough energy there to wind up another clock of the same size, and by a suitable arrangement of wheels and pulleys we could use it for this purpose at any time we wished to do so.

But if instead of this we start the clock, the weight will slowly move down, losing more and more of its energy as it goes, until at last it comes to rest at the bottom of the case. What has now become of the work which we stored up in it? Our work has kept the wheels turning and the pendulum moving, but on the turning axle of each wheel there is a little friction and so the axle is slightly heated in turning. And the pendulum, as it swings backward and forward through the air around it, is heated too. And so in this case, exactly as in the case of the blacksmith and his hammer, we see that the final result of all our work has been to send little heat waves traveling outward through the ether.

WHY SOME NEBULAS CHANGE INTO HOT STARS.

Let us now think of a great, bright cloud of nebulous matter, such as the one which is left at the center of a spiral nebula or as those which are moving around this center, and let us see if what we have learned about heat and energy will not tell us what this cloud will do.

In the first place, if we could stand at the edge of the cloud, or anywhere inside of it except at its exact center, we would find that the cloud was pulling us downward, exactly as the earth pulls us when we stand on the earth; that is, we would have weight. If we could take a little part of the cloud in our hands, we would find that it had weight too. If we should lift it up, that is, if we should move it away from the center of the cloud, we would find that we exerted some effort or did some work in lifting it. If we then let go of it, it would fall toward the center of the cloud again, and it would keep moving until it was brought to rest by the resistance of the material around it. But in being brought to rest it would have heated itself and the nebula, and this heating would be exactly as much as would balance the energy which we stored in the mass by lifting it up. It is exactly as with the hammer and the anvil: the energy is changed into heat.

We have seen that if a given weight falls a certain distance we can always tell exactly how much heat its falling will make. Now the whole cloud is slowly shrinking together; that is, every little part of it is continually falling toward its center. And this falling would always make the nebula grow hotter and hotter. But we must remember that our cloud is out in cold space where the temperature is many hundred degrees below zero, and so it is rapidly losing its heat in all directions. Will the heat made by its falling together be enough to take the place of the heat it is all the time losing, or will it be less? If it is less it is clear that the nebula will grow colder: if the two are equal it will neither grow colder nor hotter.

About fifty years ago, the remarkable fact was discovered that a shrinking nebula, even though surrounded by the intense cold of space, will actually keep growing hotter. Its pull, or gravitation, will be so strong, and its material will fall together so rapidly that more heat will be continually added to it than it can lose in space. And this will keep on until it gets so small and so dense that the material can no longer fall rapidly toward the center.

Thus a nebulous cloud will grow ever smaller and smaller, and the smaller it grows the hotter and brighter it will become. Just before it changes to a liquid condition it will be hotter and shine out more brightly than at any other time. But after this it will cool very rapidly: soon it will form a crust, and then it will become solid and cold, and its life as a bright star will be at an end.

A very large cloud will pass through these changes much more slowly than a smaller one. And so we see that our sun is still wonderfully hot; the four very large outer planets are still hot too, but the four inner planets are cold and dark except as they are warmed and lighted by the sun, and our little moon is the coldest of all. The great star, Arcturus, which is a thousand times as bright as our sun, is probably in nearly its hottest state, while at the other end of the series we see many stars and star-like nebulas whose lives as suns seem to be just beginning.

HOW THE HEAT OF OUR SUN IS CAUSED.

We have now followed the whole history of the wonderful spiral nebulas which are seen in the sky, and we have shown how each of them may change into a sun with a system of worlds revolving around it. We believe that our own solar system was formed in this way, and as this is the only system of worlds which we can clearly see and study, let us examine it more closely in the light of what we have learned.

We know that our sun has been pouring out its wonderfully great heat for many thousands of years. We know that all this time it has grown but very little hotter or colder, for if the heat which we receive from it had varied, though only a very little, the nature of the plants and animals which live on the world would have been changed. If the sun should grow even a very little colder many plants and animals which can only live in a very hot climate would die, and if it should grow hotter our world would become hotter too, and the living things which can now exist only near the equator would be found in temperate regions. But the plants and animals which lived in Europe and Asia many thousands of years ago are almost exactly the same as those which best grow there now. From this we are entirely certain that our earth receives just as much heat from the sun now as it did in those early days.

Men long wondered what kind of a body the sun could be that it could keep pouring out this great amount of heat for century after century. It was most natural to at first think that it was a great body actually burning up, just as the wood and coal which warm us burn up in our stoves. But when men learned more about heat, they found that this could not possibly be. They found that even if the whole sun were made out of the best and purest coal, and that if it were burning just fast enough to make the heat which we know it sends out, it would all be completely burnt up in less than one thousand years.

And next they thought that its great heat might be caused by meteorites which were always falling upon it from outer space. Such meteorites, as we have seen, would have all their energy of motion changed into heat, and if enough of them fell on the sun they might easily cause all the heat which the sun pours out. But the amount of this heat is so very great that a very large number of meteorites would be required to cause it. It can easily be shown that so many would have to fall continually that the sun would rapidly grow larger. And as it grew larger it would pull more strongly on the worlds which are moving around it and would cause them to move quite differently from how they are seen to do.

And so we can be sure that the sun is not really burning, nor is it kept hot by matter which falls upon it from without. But when we know how energy can be changed into heat, we can explain it all in a wonderfully simple and easy way. It is only necessary that each part of the sun shall fall a little more than one hundred feet nearer the center each year in order that the energy of this falling when changed into heat shall be exactly equal to the great amount of heat which our sun is pouring out. We certainly know that if the sun is really shrinking even so little as this, then its shrinking will cause all the heat which we receive from it.

Although the sun does not look very large to us, it is really more than eight hundred and sixty-six thousand miles through; it only seems small to us because it is so very far away. Even if all of the heat which it sends out is caused by its shrinking together, we see that it need only shrink very slowly. If it is always growing smaller just fast enough to make all the heat which it pours out, it will be at least ten thousand years before we can see that its size has changed at all, even in our most powerful telescopes.

HOW LONG WILL OUR SUN LIVE?

We know just how large our sun is and how much it weighs, and therefore we can tell how dense the material is out of which it is made; that is, we can tell just how heavy a cubic foot of our sun is. It is found that our sun is only a little heavier than if it were all made of water; a cubic foot of the sun would weigh a little less than one and one-half times as much as a cubic foot of water would do. All solid worlds are much heavier than this; a cubic foot of our earth would weigh five and one-half times as much as a cubic foot of water. Our little earth is four times as dense as the sun: it is because the sun is so enormously expanded by its great heat that it is so light.

If all of the heat which the sun pours out is caused by its shrinking together, we can find exactly how much smaller the sun must grow in every year. And as it grows smaller it will become denser. It is not hard, therefore, to find out how small it will be when it has become so dense that its material can no longer fall toward the center rapidly enough to make the heat which it is sending out. And if we know how much it is shrinking together each year, we can easily find out how many years it will be before the sun gets so small as this.

When this is all worked out, it is found that in about ten million years from now our sun will have become so small and so dense that it can no longer shrink together rapidly enough to pour out so much heat as we receive from it now. At this time it will have almost reached a solid state, and in a very little while after this its shrinking will very nearly stop. But we know that it is always surrounded by the cold of outer space; that it is ever pouring out and losing its heat in all directions and that it is only from the energy of its own shrinking that it can get more heat to take the place of that which it is all the time losing. And therefore just as soon as its shrinking stops, its heat will rapidly stream away from it and it will become a cold and dark world.

And so we find that if all the heat of the sun is caused by its shrinking, it will continue to warm our earth for about ten million years. But it has very recently been learned that all matter is much more complex than we used to think it was. We have long known that every piece of matter is made up of a wonderfully large number of very small molecules, and that a single molecule may be formed of many still smaller bodies, called Atoms. And now it is known that many atoms are themselves formed of particles of matter so wonderfully small that there are more than a thousand of them in a single atom. The motion of these little particles when they are freed from their atom may cause heat waves in the ether, just as the motions of the far larger and coarser molecules do.

This energy of motion is stored up in each atom and may be changed into heat, just as other forms of energy may. In the wonderfully hot interior of the sun, the atoms may be broken up in this way and the motion of their particles may be changed into heat, And if this is so, the age of the sun may be very greatly lengthened. But however this may be, our sun cannot last forever. Its energy, from wherever it comes, is being changed into heat, its heat is being lost in space, and a time will surely come when all the energy which in the beginning was stored in our spiral nebula has been used up. Then will begin the long night of our solar system. Whether, from a cause unknown to us, this will be followed by a new day, no man can tell.

WHAT ASTRONOMY TEACHES US.

All our knowledge, all of our reason, lead us to but one conclusion. The forms of the nebulas are slowly changing—the stars are ever drawing nearer to the time when they will shine no longer—each member of the wonderful host of heavenly objects is surely growing older. As far as we can see, all change is in but one direction. We know of nothing which can halt it, nothing which can turn it backward. Unless there are other great causes at work in our universe of which we know nothing, a time, though infinitely remote, will surely come when every nebula is dark, when the stars will shine no longer, and when our whole universe is nothing but a black, cold, lifeless cloud of matter.

But is it reasonable for us to think that this will ever be? Is this the end toward which everything is moving? It is true that all the changes which we see, all the causes we have studied, seem to tell us so, but let us see a little more clearly to what conclusions our imperfect knowledge leads us.

All that we have learned has taught us that no universe of stars can last forever. Its age may be measured in millions of millions of years, but when these have passed away its end must surely come. All around us there shines out our own wonderful and beautiful cloud of stars. The very fact that it exists tells us most clearly that one of two things must be true. Either there are wonderful forces continually acting of which we know nothing at all, which prevent the slow aging of the stars, or else our own universe once had a definite beginning.

How little do we know! We see our own great universe with its hundreds of millions of suns, but we know not how it was formed nor what its end will be. And beyond this in all directions are the wonderful depths of unending space. What countless other universes may there not be there!

Astronomy is the most sublime and exalted of all sciences. No one who studies and reflects upon its teachings can fail to feel how infinitely greater the Ruler and Creator of worlds must be than we, nor to how very little a way all our learning and reason will lead us. Sir Isaac Newton, the greatest of all astronomers who have lived on the world, felt this. He wrote of the wonderful results of his whole lifetime of brilliant discoveries and profound study:

"I know not what the world will think of my labors, but to myself it seems to me that I have been but as a child playing on the sea-shore; now finding some pebble rather more polished, and now some shell rather more agreeably variegated than another, while the immense ocean of truth extended itself unexplored before me."

CHAPTER XXII.

The Growth of Worlds.

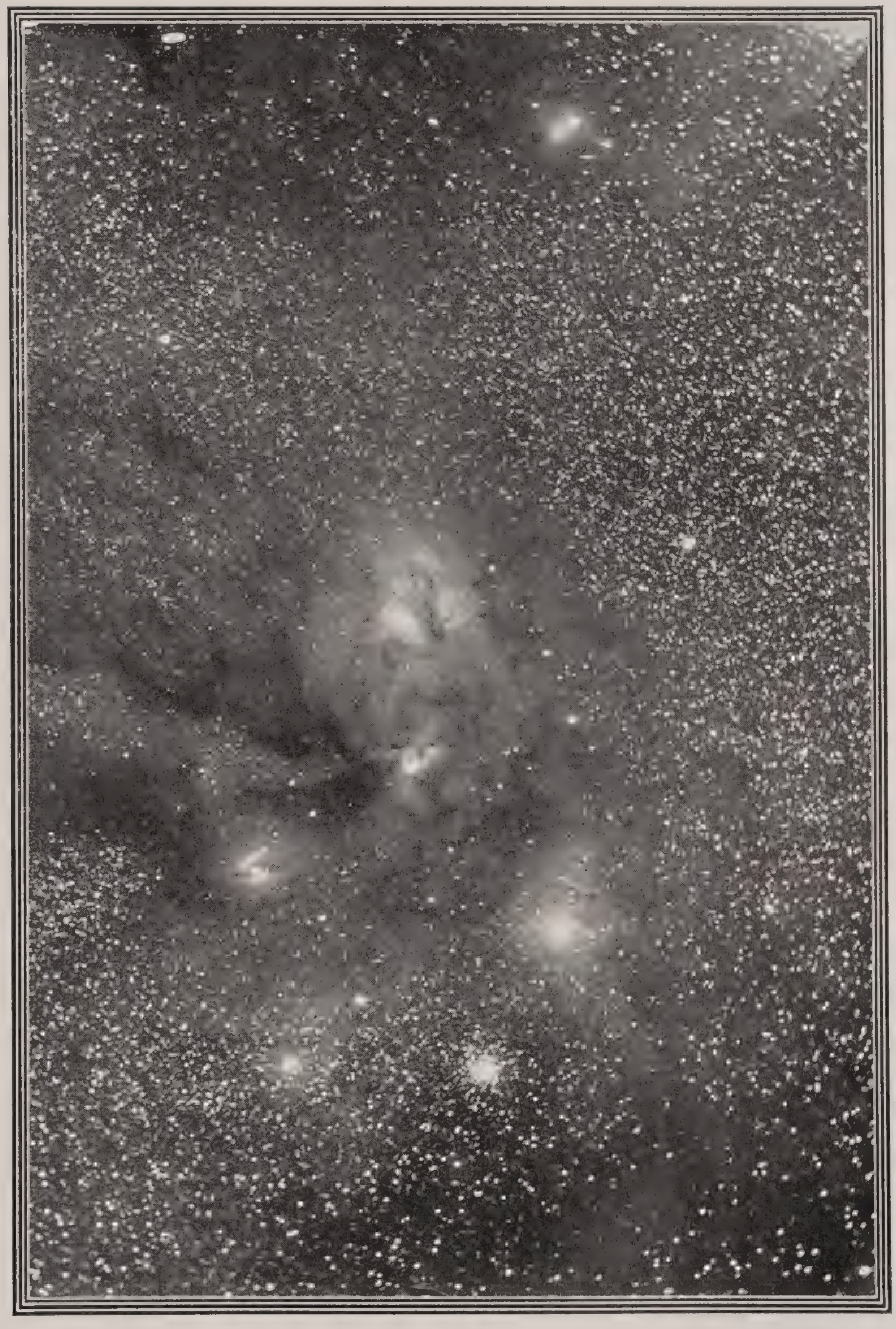
INTRODUCTION.

IN ancient times men celebrated in their epic poems the achievements of their heroes. They sang of long voyages over stormy seas, of perils encountered in unexplored lands, of heroic deeds in war. The stage of action was the known part of the world, the time covered a few years, and many of the actors were said to be direct descendents of the immortal gods. We can imagine how in the long winter evenings, before their fire-places, the old men gathered the children about them while they told the stories of the adventures of Menelaus, Agamemnon, and the fierce Achilles. It was not only the rhythm of the verses and the beauty of the imagery of these poems, but it was also the fact that they described the conflict of mighty forces and portrayed things heroic in men and majestic in nature, that gave them their absorbing interest and made them for centuries a vital part of the lives of the people.

Science is changing the world, and the stories of the Greeks no longer have the influence they once exerted. There is now nothing remarkable in a voyage across the Mediterranean or the Ægean sea; the shores of Africa are no longer an unknown land, and the end of the world is not just beyond the Pillars of Hercules; bows and arrows, swords and shields would now make but a poor counterfeit for war; and the immortal gods are not supposed to dwell on the mountain tops, in the clouds, or under the seas. As works of art the epics of the ancients have never been surpassed, but they and kindred tales can not live in the penetrating light of science, and as an important influence in human life they have passed away forever. Sometimes this is deeply regretted by those who see the loss and do not know there has been a greater gain. If science has removed the terrors of a voyage across the ocean, it has amazed us with the enormous distances of the stars; if it has robbed us of the mysteries of far-away lands, it has restored to us through the telescope and the spectroscope the wonders of a universe; if it has caused us to lose respect for the capricious ancient gods, it has filled us with reverence for the invariable laws of nature. Instead of recounting the deeds of puny and short-lived men we now consider the enormous forces and the long intervals of time involved in the origin and development of worlds. The satisfaction obtained from working on these great problems is commensurate with their magnitude and the difficulties encountered in attempting their solution.

In the present chapter we shall sketch what we have learned of "how the heavens and the earth rose out of chaos." It will be seen that science is merciless and destructive only with error; it supports truth and compels its acceptance. Consequently it assigns the reasons for its conclusions, and if they are not completely established it freely confesses the fact. The absolute honesty and candor of science are among its chief characteristics. Obviously, if we do not fully understand all the wonderful changes that take place in the tiny cells of a plant which springs from a seed and grows and dies under our observation, we cannot expect to be able to go into circumstantial detail respecting the manner in which worlds are born and flourish and pass away.

One of the difficulties we encounter is due to the fact that our experience extends over a very short time compared to that required for the evolution of a world. At the best the period of astronomical observations which are valuable for present use is only a little over two thousand years, while the geologists' study of the rocks shows that the earth has made its journey around the sun for many millions of years, and back of the point which their investigations reach stretches an age of unknown length. Our position is similar to that in which an intelligent being, the whole existence of whose race covered only a summer's month in a forest, would find himself if he wished to work out the life cycles of the many kinds of great trees surrounding him and spreading their branches in the sky above. If it were past mid-summer he would observe that each succeeding day the sun would be farther south and the period from dawn to dark would be shorter. For the brief interval covered by his observations the change would be sensibly regular and uniform, and hence he would be led to the conclusion that the cold and darkness of eternal night were coming on when all life would be forever extinguished. This conclusion, based on altogether insufficient evidence, would, of course, be false. But if he examined the branches of the trees with care he would find the scars of fallen leaves, and he would rightly infer that they had dropped because of cold and that new ones had appeared with the return of favorable conditions. If he cut down a tree he would find its trunk made up of a great number of concentric rings, which he might interpret as having been produced by periods of rapid growth with unfavorable intervening ones in which the wood became tough and hardened. From observations of the rate of growth of the trees and measurements of the thickness of the rings, together with an estimate of the intervening periods, he might conclude that the time required for the development of a ring was eight to twelve times the life-time of his race, or what we call a year. Let us suppose he compromised on the approximate value ten. The fact of the cycle would be secure; the time required for it, less certain. Then, if on the trunk of some tree he counted five hundred rings, corresponding to the five hundred years of its growth, he would be forced to the conclusion that it had lived, growing in summer and swaying in the storms of winter, five thousand times the life-time of his race. This would seem an eternity to him, but if he possessed the powers of imagination necessary to interpret the results of his observations and calculations, he would accept the conclusions as true and go on to new discoveries. His theory would be confirmed by the fact that there would be around him examples of trees in all stages of their evolution from the tiny saplings, which he could tear from the ground with his hands, to the giants towering above him fifty times his height. He would also find some which, though standing, were dead, and others which had crashed to the ground and whose moss-covered trunks were crumbling with decay. He might see somewhere in the forest a ridge produced by the remains of a great tree which long before had fallen; and little ones growing from it would show him how trees develop slowly from saplings to maturity, and then dying and decaying, become food for later generations. His theory would be, as we know, so far essentially correct. But if he assumed that the leaves of all trees fall in the winter, that there are winters wherever trees grow, that they all live as long as the ones whose rings he had counted, and that the cycle of growth, death, and decay had repeated itself forever, he would, of course, be partly wrong, for there are trees whose leaves do not fall with the coming of the frost, there are places on the earth where there are no winters, the life-times of trees vary greatly, and geology shows us that every part of the earth, because of encroachments of the sea, or lava flows, or sheets of ice, has at some time been unsuited for the development of plant life. In short, while his conclusions in the main and in gen-



A part of the Sky above the bright Star Antares, with thousands of Stars and a great Nebulous Cloud. To the left are great rifts from which the Stars seem to have been swept away.

eral outline would be correct, they would be less exact the further they reached, in both space and time, from the things which had been actually under his observation.

In a similar way we human beings can study in some detail a small part of the universe for a short time. The cosmical processes are so slow that we cannot hope actually to observe any important changes in the celestial bodies, but from an examination of them in various stages of their development we can arrive at approximately correct ideas regarding the course of their evolution. A serious difficulty in the investigation is due to the fact that probably there are many distinct lines of development of worlds, as there are of trees, and it is not easy to separate them. Naturally we are most interested in, and can most easily investigate, those series of changes which the sun and planets, including the earth, have come through; and these results will enable us to determine with some degree of certainty what the future has in store for them. We shall, then, take up the discussion of the origin, development, and decay of worlds, particularly such as the members of the solar system, and the results reached will give a new meaning to the shining stars, which, on a cloudless night, fill the heavens.

ELEMENTAL WORLD-STUFF.

The thousands of words in the English language are made out of twenty-six letters. Similarly, the thousands of different minerals and vegetable and animal substances which are found on the earth are made out of about eighty kinds of fundamental materials called the chemical elements. The character of a substance depends upon the elements of which it is composed and the manner in which they are grouped together. The simple substances, such as water, are made out of only a few elements and only a few units of each; but those which are complex, such as are found in the tissues of plants and animals, are usually made of many elements and many units of each. If the material universe on the whole changes from the simple to the complex, or if it passes through cycle after cycle, it is convenient in describing its evolution to begin with matter in its simplest form. For this reason we start with such unorganized masses of the chemical elements as are shown to exist by our observations.

We have learned how in the heavens there are great numbers of tenuous, wide-spread masses of enormous dimensions, called nebulas, and the spectroscope proves, at least in the case of the brighter ones, that they are the ordinary elements in the gaseous state. When we remember that the stars are on the average so far apart that it takes years for light, traveling as fast as the lightning, to go from one to another, then we get some faint idea of the magnitude of the portions of space across which these webs of primitive world-stuff stretch.

At present we know nothing positive regarding the origin of this material. If it is the direct creation of an Infinite Being, then we are justified, because of the different stages of development in which matter is found, in drawing the conclusion that all the time it is being created, just as our intelligent being in the forest would correctly infer that trees all the time are sprouting from seeds. But as trees grow and decay and the material of which they were composed reappears again in other trees, so it may be that nebulas, instead of being newly created matter, are but one stage in a cycle which is repeated time and time again. Indeed, this view seems more in harmony with that which we positively know in other lines from actual observations, but the cycle of cosmic changes, if it exists, is so vast and our knowledge is yet so limited that it is not possible to make more than rough outlines of the course of organization and dissolution. It may be noted, however, that an orderly development of matter from the nebulous state to finished worlds, or through cycle after cycle, is more wonderful than direct creation, and at least to the same extent implies the presence of Supreme Intelligence in the universe.

THE DEVELOPMENT OF STARS.

The spectroscope shows that the nebulas are composed of the familiar simple elements, which lie all about us, and thus proves the essential unity of the visible universe. It seems to be a safe assumption that the properties of matter do not depend upon its position in space. Consequently, we conclude that under the action of chemical forces chemical compounds are formed in those distant bodies, and that the attraction of gravitation draws their wide-reaching parts into denser and denser masses. When the nebulous matter is fairly homogeneous and the various parts have only small motions relatively to one another, a single star may result; but if there are several denser nuclei in the original material, and if they have considerable relative velocities, several stars will be formed. It is generally supposed that a single star having very rapid rotation may break up into two or more separate ones.

We have learned that in the process of condensation of a nebula to a star an enormous amount of heat is developed. The particles rush together under the impelling force of gravitation and the energy of their motion raises their temperature when they strike, just as the energy of motion of a bullet changes to heat when it finds the target, or as that of a meteor burns it up when it encounters the resistance of the air. Therefore, even though a nebula were relatively cool, if it should condense into a star the star would be extremely hot, and in general, the temperature would rise as long as rapid condensation continued.

We now inquire whether the telescope furnishes examples of matter in the various stages of the evolution which have been briefly described. If so, since its steps are in harmony with the known properties of the material with which we are familiar here on the earth, we have a right to conclude that the theory contains important elements of truth. But that it is not the whole truth is certain, for the stars differ so much among themselves that they cannot all have had the same history. We should deceive ourselves if we claimed more, and therefore we leave the picture in outline knowing that with the increasing knowledge of the future the various details of light and shade and color will be supplied.

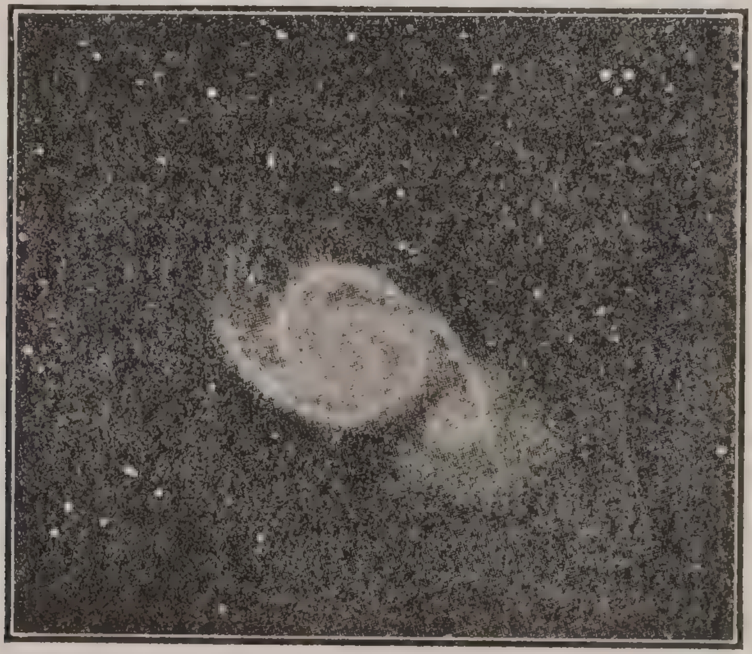
Observations show that not all the nebulas are veil-like wisps of unorganized matter. They are found in all stages of condensation from the tenuous webs in Cygnus to the finished stars. The magnificent Orion nebula, one of the most splendid objects in the whole heavens, is an example of what may be called the second stage in the evolution of suns. The gases are denser than those in Cygnus and the matter is becoming organized, as is shown by the distinct waves in the rolling clouds of world-stuff. The forces and masses involved in this evolution are so great they are beyond the powers of our imagination. While we do not know the distance of the Orion nebula, and consequently cannot accurately measure its vast volume, there are good reasons for believing that several years are required for light to speed across it. Compare this to the little solar system. The light comes from the sun to us in eight minutes, and goes from the sun to the most remote planet in four hours. Or, perhaps we shall understand the relations better if we note that the sun is a million times as large as the earth, that a sphere having the diameter of the solar system is two hundred million times as large as the sun, and that the Orion nebula is six hundred thousand million times as large as this sphere. There is apparently enough matter in it for thousands of such suns as our own, and it may well be that it is evolving into a vast system of stars instead of into a single one.

What appears to be a later state in stellar evolution is exemplified by the Pleiades, the Seven Sisters of the ancient Greeks. With the unaided eye they seem to be seven small stars; little jewels, in a crystalline sphere. Through a telescope they are seen to be blazing suns, and a very large instrument shows they are involved in nebulous matter reaching from star to star. A discussion of their motions and distances leads to the remarkable conclusion that they are from two to three hundred times as large as our own sun. They appear like tiny points because they are so far away in space that it takes light three hundred years to come from them to us. The light with which we see them left those distant stars about the time Galileo invented the telescope, and two hundred and fifty years before the development of photography. We are at present, however, not interested primarily in their distances, or in their dimensions, which are comparable to those of the Orion nebula, but in the fact that they are examples of an evolution from a nebula to stars which is near its completion. The connections of these nebulous masses with the principal stars of this group show their fundamental relations to them, and it is hard to escape the conclusion that ultimately they will be drawn by gravitation into the relatively few centers.

The fourth stage is the stars themselves, of which several hundred millions are within the range of our present powerful instruments. There are, of course, infinitely many intermediate steps in the evolution, but the four stages which have been given are sufficient for general outlines. There is no means at present of arriving at even an approximate idea of the length of time required for these changes, but probably it should be counted in hundreds of millions, if not in thousands of millions, of years.

SPIRAL NEBULAS.

In the evolution of stars so far considered there seems to be little chance for the development of an orderly system of planets. There have been hypotheses, indeed, of a sun shedding rings which later condense into planets, but the difficulties connected with such theories compelled their general abandonment a decade ago. There is, however, another class of celestial objects, the spiral nebulas, whose character is such that it seems inevitable that they will evolve into systems consisting of central suns attended by numbers of secondary bodies revolving around them nearly in the same plane and in the same direction. These nebulas have recently been found to be very numerous, in fact, many times more numerous than all other kinds combined. The great majority of them are so small and faint that they are detected only with the most powerful, modern, photographic telescopes.



The Whirlpool Nebula.

The nebulas heretofore considered and the spiral nebulas are fundamentally distinct. The former shine with the pale green light of simple gases and they are undoubtedly tenuous and primitive world-stuff; the latter emit the steady white light which is radiated by matter in the solid or liquid state. The former are irregular and varied in shape, and in their earlier stages show no evidences of organization; the latter are perfectly consistent in having a massive central core with two generally well-defined arms winding out from it. In all their important characteristics the two classes of nebulas are separated by a gulf which additional discoveries not only do not bridge, but make the more distinct. They certainly have had different origins, they cannot represent consecutive stages in an evolution, and they lead to different final results.

Just as the truth or falsity of the theory that stars develop from such nebulas as that in Orion is independent of the manner of their origin, so the correctness of the theory that the solar system has grown to its present state from a small spiral nebula does not in the least depend upon the genesis of these curious masses. But the story will not be complete until we know not only what they are and into what they are developing, but also whence they came. For this reason we are justified in attempting to find the solution to the question of their origin; and if the answer be in doubt it is only scientific to admit it.

The suggestion has been made that spiral nebulas are formed when two suns pass near each other. It is clear that, in a system of hundreds of millions of suns moving on the average several hundred million miles each year, these close approaches must now and then occur unless the motions of the stars are much more systematic than there is at present reason for believing. It is found upon investigation that if the stars are supposed to be moving quite at random a given star will, on the average, pass as near another star as the earth is to the sun once in a billion years. Therefore, if spiral nebulas are formed when suns pass one another at this order of distance we have a rough idea of the life-time of a system of planets. Indeed, whether such an approach produces spiral nebulas or not, we have a measure of the life of planets, for one sun passing so near another would sweep away and destroy these tiny bodies as though they were dust. On our sun there are now frequent explosions in which immense masses of liquid and vaporous rock material are thrown up from its surface farther than from the earth to the moon. These glowing streams, like rockets, ascend in long graceful paths, and, curving over at the height of a hundred thousand miles, rush down faster and faster under the impulsion of the gravity to which they are subject and plunge back into the fiery surface of the sun again.

Imagine now the condition when a star is passing at the distance of the earth. Enormous tides will be raised in the sun on the sides toward and opposite the visiting star, and in these directions matter will be ejected most abundantly and to the greatest distances. Instead of falling back upon the sun as it does now, the rapidly passing star will draw it toward itself across the line of its ascent and, as detailed computations have shown, in many cases leave it revolving around the center from which it was expelled. The many ejections altogether will produce a spiral nebula having two opposite arms on which will be nuclei of denser masses here and there. The curved branches of a spiral are not the paths along which the material moves; rather it goes across them and revolves around the sun in the direction opposite to that in which they wind out from the central mass. The remote and smaller parts, in the course of time losing their heat and electric charges, become opaque; and when a nebula is presented edgewise to us, the dark materials produce by eclipse a black streak along the center of its disk.

While the suggested genesis of spiral nebulas is based on sound dynamics and agrees fairly well with the facts established by observation, it would be rash to claim it has been proved to be true. Alternative hypotheses would be heartily welcomed, but those so far advanced seem to be in harmony neither with dynamics nor with the results of observation. The existence of spiral nebulas, being established by the observations, is not in doubt and we have a right, therefore, to use them in our theories of evolution. The uncertainties respecting their origin are among the things in which our work is as yet incomplete.

THE PLANETESIMAL HYPOTHESIS.

Two fundamentally distinct theories have been developed respecting the origin and evolution of the planets of the solar system. One, dating back more than a century and associated particularly with the name of the great French astronomer Laplace, supposes they were formed by the aggregation of large masses of heated gas detached as rings or otherwise from a contracting and rotating solar nebula. Without a detailed discussion, it is clear that this hypothesis leads to the picture of an originally gaseous earth which gradually cooled and hardened to its present state. The other, of recent origin and called by Professor Chamberlin the Planetesimal Hypothesis, starts with the essentially different conception of many small masses revolving around the sun in independent orbits. The small masses moved like little planets, whence the name of the theory, but by collisions they, in time, all became united in a few larger bodies. As will be seen later, the early history of the earth was quite different if this theory is correct from what it was supposed to have been according to the other. The disproof of the old conceptions of the origin of the planets, and the establishing of the Planetesimal Hypothesis as a working theory are the contributions to cosmogony made in recent years.

The matter making up the arms of a spiral nebula is in the planetesimal state. If the truth of the Planetesimal Theory had not already been indicated by the character of the earth and the phenomena of the solar system itself, the abundance of spiral nebulas would have suggested the idea that our system has evolved from a small one of these objects. The one from which the solar system may have evolved must have been very small, probably even smaller than the countless numbers of those which are almost beyond the reach of our most powerful instruments. Here and there along the arms of the nebula are knots of denser matter, or *nuclei,* as they are called. Each individual nucleus and smaller mass moves around the central sun in an elongated orbit which is nearly elliptical in shape. These orbits are not exactly concentric and the directions of their longest diameters continually change; consequently, they will cross one another and collisions can take place. A result of the collisions will be that the nuclei will grow larger and larger by the addition of the finer material until little or none is left. When the process is essentially complete the revolving planets will sweep up only a little meteoric matter as the earth does now. Thus there is finally a central sun having a number of smaller bodies revolving around it nearly in the same plane and in the same direction.

An important result of the collisions is that whether the nucleus overtakes the smaller mass, or the smaller mass the nucleus, or they strike in any other way, the orbit of the nucleus is, in general, made more nearly circular. Therefore, as planets grow, their orbits become more nearly round, and, other things being equal, those revolving in regions which were rich in the fine material will at the end have the most nearly circular orbits. In harmony with this result and the Planetesimal Theory of the origin of the solar system, the observations show that those planets which are the largest and which presumably have grown the most, actually revolve in the least elongated paths.

Another conclusion of a similar nature is that as planets grow by collisions their orbits tend to come into the average plane of motion of the system. A hasty examination of the question might lead one to infer that this is not so, but its truth becomes evident in the extreme case in which all the revolving bodies unite in one. Again, the implications of the theory are in harmony with the observed facts, for the planes of the orbits of the larger planets are nearly coincident, while those of the smaller ones are in some cases considerably inclined.

When a nucleus sweeps up a smaller mass its rotation is slightly modified by the collision. An investigation of the character of the change produced shows that in general they tend to give the nucleus a rotation in the same direction as that in which it revolves around the central sun. Obviously a tiny meteor, or even a mass as large as a mountain, would have only a small effect upon the rotation of a world; but the influences of the collisions are never lost, and accumulating during the whole period of growth of a planet, they might well be the determining factors in the direction of its rotation. The sun and all the secondary bodies of the solar system whose rotations are known turn on their axes in the direction in which the planets revolve. There is no other explanation of this remarkable fact than that which has just been given. This discussion is sufficient to establish the perfect agreement between the implications of the Planetesimal Theory and the principal phenomena of the solar system.

THE EARLY HISTORY OF THE EARTH.

Let us start with a nucleus having a mass a small fraction of that of the present earth, and revolving around the sun in a region rich in the finer material of a spiral nebula. Originally, it was so feeble in gravitative power that probably it could not hold the swiftly darting particles of an atmosphere from escaping into space. In harmony with this statement, it may be noted that it is inferred from theory and proved by observations that the moon and Mercury have no sensible atmospheres.

A small body, such as that with which we have started, if unprotected by an enveloping atmosphere, rapidly loses its heat into space and becomes cold, at least on its exterior. But another factor is involved. The earth-nucleus was subject to the continual bombardment of the nebular material. If it descended in a deluge of the finer matter with now and then a mass of mountain size, the heat developed by the impacts may have caused it to blaze like a furnace. But if the process of aggregation was slower, as seems more reasonable in view of the smallness of the earth and the immense spaces traversed in its orbit, its temperature was always more moderate.

As the earth-nucleus grew, the original mass and that which fell on it first were buried beneath an enormous load. A little computation shows that the pressure could easily have become a hundred tons per square inch. This crushed and squeezed together the porous and irregular fragments which came from the sky, and in the process a large amount of heat was developed which, in the solid mass, was conducted to the surface but slowly. If the original nebular material were no denser than the meteorites which now fall upon the earth, investigation shows that the heat developed in this way would account for all the internal fire of which there is any positive proof. Hence we may form the picture of an earth whose surface has, on the whole, been cool during the entire period of its growth, and whose interior, though solid, has been highly heated by its contraction because of the weight of the material above.

With the growth of the earth-nucleus its ability to hold an atmosphere in gravitative control increased. When it arrived at approximately the mass and dimensions of Mercury the heavier gases could no longer escape. But one may ask the source of these materials. Since both the rocks in the earth at present and the meteorites which fall from the sky hold locked up in countless little prison cells among their particles, as well as in the more intimate relations of physical and chemical union, large quantities of gas which can be expelled by crushing and heating them, the answer is that the atmospheric particles came from the wandering nebular masses, some given out when they broke in fragments on the solid earth, and more released later from the compressed and heated interior. Thus the atmosphere grew, and it was doubtless always as great as the growing earth could hold. But nebular masses were long ago sensibly all swept up, and hence we may inquire whether the possible present losses are in some way balanced by corresponding gains. The crumbling surface rocks give up their gases still, while mineral springs, spouting geysers, and smoking volcanoes pour out vapors from greater depths. But the fact that a world can lose its atmospheric particles implies that the spaces through which the planets journey round the sun swarm with these tiny bits of matter, for the great central mass would still hold them in its gravitative control. There is observational proof of it in the soft wedge, called the zodiacal light, which reaching up the western sky after the sun has set, or in the east before the dawn, proclaims returning day. Therefore, though molecule after molecule escapes from the air, others in the same way return, and in the course of time, whatever the initial state, a condition of balance between the loss and gain will be reached. The earth has run so long that we may safely conclude that in its case the equilibrium has been attained. And all that has been said of the atmosphere respecting its origin, the way it leaves the earth or comes to it, applies with unimportant changes to the water, which is not only on the earth as a liquid, but also to some extent mingles with the air above in the vaporous state.

We naturally inquire how long a time elapsed between that when the earth-nucleus first began its independent journey around the central sun and that when, full grown and with an atmospheric envelope, it finished sweeping up the nebular waste moving near its path. The uncertain factors are so numerous no definite results can be reached; but from the fact that the earth is almost infinitesimal in size compared to the zone which it has cleared, and that even if its orbit originally intersected the curve described by a smaller mass the exact condition of arriving simultaneously at the meeting place would seldom be fulfilled, it is evident that long ages were consumed in the process. A million years probably were altogether too few for the completion of so long a task, and a hundred million years does not seem an extravagant estimate.

THE ACTION OF AIR AND WATER.

Consider the earth when nebular matter tumbling from the sky had added to its mass until air and water could be held. For simplicity suppose that its period of appreciable growth was nearly at an end. That was the time when the interior rocks were being crushed and squeezed, with generation of heat, and the surface wrinkled into mountain ranges. Here and there huge masses of liquid rock material were forced up from the heated depths, spreading far and cooling when they reached the air. These things but added to the wild disorder on a surface already chaotic with enormous heaps of fallen meteors and with intervening holes where masses of mountain size, descending with the speed of rifle bullets, had smashed the rocks and buried themselves below.

The moon now presents a surface torn and scarred by the violent forces of its youth, but the original hills and mountains of the earth have disappeared. The chief reason for this difference in worlds so near together and so closely related in their origin and early history is that on the desert moon no winds swept across the lofty peaks and no water gullied the steep inclines or shaped the sides of the hollows, while on the earth for a thousand times a thousand years, and more, the winter storms and the summer rains beat upon the granite shoulders of the mountains and changed them into powder. At times, as now, the rushing streams and rivers were turbid with the waste of hills which they carried down into lakes and oceans; and at others the breezes picked up their pulverized remains and sifted them over the valleys. Thus the original mountains disappeared. The mud and dust, deposited in horizontal layers, a thin film each year, changed back again to rock, and the fact that now in many places its strata are piled to a depth of thousands of feet proves that enormous masses were disintegrated.

It has been found from delicate observations of the stars and measurements made with pendulums that, at the moderate depth of perhaps one hundred miles below the level of the sea, the pressure is nearly the same under the oceans as under the land. Probably in this respect conditions were much the same when the meteoric masses first settled firmly into place. As the mountains were washed away this equilibrium was disturbed, but the new mountain ridges which were forced up restored the balance. All the snow-clad peaks which now penetrate the clouds are of this later origin, and the warped and folded strata lying high along their sides prove they have been elevated from what once were valleys.

THE FUTURE OF THE EARTH.

In the winter when the grass and flowers are buried beneath the snow and the wind whistles through the barren trees, the old man, relying on a life's experience, doubts not Spring will return and that under another summer's sun the prairies will be covered with blossoms and the forests will be banks of foliage again. Similarly, the scientist, whose knowledge has been extended by careful investigations into the past, ten thousand times the life-time of a man, believes that those cycles of change which many times have been repeated will, under similar circumstances, take place once more. Not only has the scientific man the advantage of information reaching far back across the years, but also he has learned certain of nature's fundamental laws which enable him to determine what will happen in the future even though conditions are not exactly as they have been in the past.

Day after day, for a hundred million years, the sun has lighted and warmed the earth with its abundant rays. The cycle of day and night is but a unit in the larger one of seasons, and the seasons themselves are units in greater cycles still. Repeatedly in recent geologic times great masses of snow and ice have slowly pushed their way down from the table lands of Canada, spreading from the Allegheny Mountains to the slopes of the Rockies, and reaching as far south as the banks of the Ohio and the Missouri. For thousands of years these mighty glaciers were creeping along the slight inclines, writing on the hillsides the records of their journeys and piling up great ridges of soil and gravel and rounded boulders where they stopped and melted. During intervening periods of probably equal or greater length these same regions enjoyed climatic conditions which were much as they are at present. From the dim records of a more distant past it is found that these rhythmic changes were units in greater ones of a similar nature. At one time the snow and ice of continuous winter covered parts of the earth both sides of the equator down even across the tropics. At another, even to the poles the air was warm and balmy, for palms and magnolias grew in Greenland, while at the opposite end of the earth layers of coal were made from vegetation. There were other cycles than those of temperature. At one time in semi-desert Arizona abundant rains fell and the petrified remains of great trees show us now the type of forests that then covered its hills. On the other hand Michigan and New York are now dotted with lakes and nearly surrounded by water, but once they were arid, for within their borders are found deep beds of gypsum and salt which were left behind by vanishing seas. These are examples of the great, approximately rhythmic changes the earth has experienced.

Judging the future by the past, we may conclude that for millions of years to come the sun will shine with undimmed luster. But as it pours out its energy at an extravagant rate its store of it is always diminishing and it seems probable that the time will come when its light will fail. If we knew more exactly all the sources of its heat and to what extent the disintegration of radio-active matter feeds its fires we might compute how long it will yet move in splendor across the sky; but all we can reasonably say is that in the future it will warm and light the earth for a time comparable to that which has elapsed since the planets were scattered along the arms of a spiral nebula. And doubtless in these future years, as in the past, there will be long periods of unusual cold when the land in the higher latitudes will be locked in ice and snow, and others in which the soft winds of a temperate climate will blow over the poles; there will be ages when portions of the earth in a desert state will bake under a cloudless sky, and others in which vegetable matter will accumulate in great marshes kept wet by abundant rain. In short, it is scarcely less than certain that the great oscillations of the past will be repeated in the future over and over again, for there is now no more reason to suppose that conditions will henceforth be uniform, or steadily changing in one direction, than there would have been to have made the supposition at any corresponding previous state. But perhaps before the unfavorable days shall return, man, by his science, will have gained such control over the forces of nature that arctic blasts and torrid heat and droughts and floods not only will have lost their terrors but will have become his servants.

Beyond these cycles there is that in which stars pass near stars, destroying the existing worlds and, in the spiral nebula form, giving birth to new. We, whose experiences have been so brief, with difficulty picture to ourselves events separated by so many years. That the trouble is entirely in our little selves is shown by the fact that we easily conceive of collisions of molecules in a gas, though they are as far apart relatively to the times of oscillations of the vibrating corpuscles of which they are made as the near approaches of suns are to the periods of revolving planets. How much greater the task to bring clearly into view the possible greater cycle of nebula to star and back to nebula again! That process of aggregation is not entirely beyond our grasp, but at present we grope for that of dissolution with hints from the electrified particles which stream out from the sun.

Though the study of the growth of worlds shows us that physically we are weak and small and that our lives are short, it gives us new and greater respect for the mental powers with which we determine how nebulas condense into blazing suns, and how planets start, develop, and finally die. As our telescopes, which are ten thousand times as keen as the natural eye, penetrate the depths of space and reveal its wonders to our gaze, so do our reasoning faculties reach out in time across the countless years and bring the events of almost an eternity into view. The higher the eminence of accumulated fact from which we explore the distant haze and gloom, the clearer and more certain becomes our vision. Hence the more we patiently search the earth and scan the sky the more of the universe in both space and time is brought into our experience, and experience is life itself to intelligent beings. Time is not only measured for us by a circling world, but more by the number and variety of thoughts which flash in our consciousness. Therefore, to the extent that our reasoning powers bring forward the past and anticipate the future do we, by our logic, achieve immortality.

PART II.

The Earth Our Home.

CHAPTER XXIII.

How Lands Are Worn Away.

THE STUDY OF OUR WORLD.

FROM all that has been said in the first chapters of this book, we learn that our earth is a very little world indeed. When we think of the thousands of millions of other worlds around us, the little ball on which we live seems nothing more than a very small grain of dust in a great cloud of worlds and suns which stretch so far away from us in every direction that we have not yet found the least trace of any end to it. If we were visitors to our universe from some far distant region, we would probably not spend much time in studying so small an earth; as we journeyed through the wonderful star cloud we would doubtless find very many much larger worlds than our own, which would be even more wonderful and interesting to us than this one.

But we little creatures have been appointed to spend our lives on this particular little planet. For this reason it is of more importance to us than all the other worlds together. And because we live upon it, we can find out much more about it than we can of any other world. We can travel from one country to another, and we can take the different rocks and earths of which they are made in our hands, and by studying them we can tell how the different lands came to be formed and what was happening there many long ages ago. We can make deep holes in the ground, and find that always, wherever the hole is dug, if we go down far enough we will come to a great mass of solid rock which we believe forms the whole inside, or core, of the earth. For, as we will see later, all the sand and ground and other things which we see covering the surface of the earth are only a thin layer on the outside of this great core of solid rock.

In a láter chapter we will tell how men measure just how large our world is, how they prove that it is a round ball, forever turning with very great speed, and how they find just how much the great ball weighs. We will learn about the action of the great glaciers and ice fields of the North, how islands are formed in the sea, and of a few of the many wonderful things which we find about us on our world today. But even more interesting than all this is the study of the life of the world; how it was once all very different indeed from the world we know, and how it is even now forever slowly changing so that it will become a still different world in the far distant future.

As we look backward we see long ages in which very wonderful changes took place, and the conditions on our earth during each age were so very different from what they were in other ages that it is almost as if the different times belonged to different worlds. In the beginning we see a great hot world, so hot that all of the waters which now form our lakes and oceans were changed to steam and formed a wonderfully heavy, dense, hot cloud around our planet. And next we see a much cooler world; a world so cool that much of the water which had hung above it has rained down upon its surface and formed great seas; a world for the first time separated into great regions of land and water. But the continents of this early age were not the continents which we know now. The old lands in some places were to sink under the hot seas, and in others the bottoms of the seas were to be lifted up to form new lands, so that the whole face of the earth was continually changing.

By and by the world became so cool that the most wonderful thing of all began to happen. In the waters of the early seas there began to appear the very simplest forms of animal and plant life. From this time our world is no longer a dead mass of rock and gases; it is a living world, and as age after age passes away the very simple forms of life will go through most wonderful and surprising changes, until the lands and waters of our planet become swarming with an infinite variety of living things.

Through all the ages that the living things of our earth were changing and multiplying, the face of the world was changing too. Land was being worn away and carried to the bottom of the sea, where it was slowly made into rocks, and much of it was afterward lifted above the surface of the water again. And inside of these rocks we find the remains of the many wonderful animals which lived on our world once but which live here no longer. And the climate of the world kept changing through the ages. At one time it was very hot and wet; at others great sheets of ice crept down from the North and covered all of North America and the Northern United States. And these changes had much to do with changing the kinds of animals and plants which could live on the earth.

How do we know that all these things happened? How did men learn how rocks were made, how the continents and seas keep changing their forms, and how there were different ages when everything on our earth was so very different from the world we know? They found it all out by studying the things we find around us on the world, and the changes which even now are ever taking place. And so, before we tell the story of the past life of our world, we must learn about these things too. We must learn what things are wearing our lands away, and what are building them up; how rocks are very different from one another, and how some of them were made. And when we have learned about these things it will not be difficult for us to understand a little of what our world has to tell us about the wonderful things which have taken place upon it.

HOW ROCKS ARE DESTROYED BY WATER IN THE AIR.

In telling what it is that is slowly changing the land and rocks of our world we must speak first of the water in our atmosphere, because this does much more in wearing away the land than all other things together. All the land and all the rocks throughout the world are at the bottom of the great ocean of wet air which is always above us, and everywhere they are always slowly being changed. When we see or read of the great effects brought about by violent storms, or earthquakes, or volcanoes, we may think that it is sudden and imposing things like these which have most to do with changing the face of our earth. But this is not so. The water in our air is always quietly doing its work; day and night, winter and summer, it is always acting, and a very great deal of the change which is gradually made in the form of the continents is due to this cause alone.

One of the most important ways in which the water in our air destroys rocks is by dissolving them, just as you may see water dissolve salt or sugar if you pour it upon them. But some rocks are dissolved away very much more slowly than others. Perhaps you have seen the kind of rock called Granite. This is one of the many kinds of very hard rock which are called Igneous or Fiery, because it is believed that they are part of the very first rocks into which our melted earth hardened; we think that they are in very much the same condition as they were when they were first formed at the very beginning of our world. Granite is a very valuable rock to use for building because, as masons say, it "weathers well," that is, it does not seem to be injured at all even after many years. But if we study a small piece of it with a microscope we will see that under the action of the wet air it has really begun to change. Here and there certain parts of it are being slowly dissolved out, and after a long time the whole will fall to pieces.

Very many of the softer stones are what are called Layer Rocks, because they are found in great beds or layers, and, as we shall see later, they have a most curious and interesting history. Unlike the fiery rocks, they did not exist when the world first became solid, but they were made in later ages. It is principally in these rocks that the remains of the wonderful animals which used to live on the earth are found.

One of the commonest of layer rock is called Sandstone, and this is also often used for building, although it is not nearly so hard as granite. Some sandstones are so coarse that they look just like a great many large grains of sand, glued or cemented together. And this is just what all sandstones are. Once each of their little particles was a separate grain of sand along the shore or at the bottom of some early lake or sea, and in time the sand grains became cemented together into one great layer of rock. Some of the sandstones, as for example the oilstones which we use to sharpen knives, may not look as if they were made in this way, but that is only because each of the little grains in them is so small. If we look at them with a microscope we at once see that they too are nothing but a great many little grains of sand cemented together.

Now as soon as rain or wet air touches this sandstone it begins to dissolve away the cement which holds the grains together. Sometimes in only a very few years the outside of a sandstone rock becomes nothing but loose sand, and in time the stone becomes so soft and crumbly that it may be broken to pieces with the hand. And a few years later, what had been a hard rock has been changed into nothing but a little pile of sand. Some sandstones, however, last very much longer than others, because the material which cements them together does not dissolve so easily in water.

There are a very great many different kinds of rocks in the world, but few of them are harder than granite or softer than sandstone. And this action which we have described as destroying these two rocks is also destroying all. If you should examine any great mass of rock carefully you would find that it was not all alike; some parts of it are made of harder or softer materials than others and the water can dissolve some parts of it faster than others. And so it happens that these parts are dissolved away first and that then the rock usually falls to pieces. Every great cliff, every great mass of rock which you have ever seen, is being always destroyed in this way. And at last it will be changed into little particles of ground or earth, and washed down into the valleys or into the sea, or perhaps be blown far away as a fine dust by the wind. But in the destruction of great masses of rock the water is often very much helped by something else, and that is the action of frost in the winter time.

HOW FROST HELPS THE WATER TO DESTROY ROCKS.

If you look at a great mountain ledge or wall of rock from some little distance away it will probably look to you like one solid mass of stone but if you go close to it and examine it carefully you will see that it is very far from being solid. Running all through it are a great many little cracks, and whenever it rains, or when the air around the stone or the ground above it is very wet, these little cracks become filled with water.

You know that whenever water freezes it expands or swells, so that the ice made from the water takes up more room than the water itself did. And this expanding force of water is very great indeed. The experiment has been tried of filling thick iron bombs full of water, tightly closing the holes through which the water was poured, and then placing the bombs out in the cold. As soon as the water began to freeze, its pressure became so very great that the thick iron bombs cracked or broke to pieces with a loud noise.

In just the same way, if the weather becomes so cold that the water which is in the cracks of the rocks begins to freeze, it will swell with enormous force and break the rock to pieces. In this way a very great many irregular pieces of stone are constantly broken off of all cliffs and ledges of rock and they fall or roll down the mountainside and form great piles of broken stone. If the next time you visit a hilly region where there are large rock masses you will look on the ground near their foot, you will find great piles of rough stones which have been broken off from the rock above by the action of freezing water.

In countries where there are high, steep mountains, great masses of rock are sometimes broken off at once, especially if the mountains are in a cold climate. In this way, along the mountains of Alaska, enormous stones are sometimes blown off with a loud noise, and they go falling and bounding down the steep mountain sides, until they at last come to rest in the valleys below. In many countries the mountain roads are made very dangerous by such falling stones.

HOW RAIN WEARS THE LAND AWAY.

From what has just been said we see how by the quiet, unceasing action of the water in our air, all the great, rocky, mountain ranges and every smaller rock and stone in our world is being slowly dissolved away. Although the action of frost often helps in this destructive work and renders the wearing down of mountains and cliffs much more rapid than it otherwise would be, yet, even in countries where there is no frost, the slow but certain destruction is always going on. The little fragments or particles of stone when they become separated from their parent rock will work their way downward toward the valleys below. Their motion downward would go on very slowly indeed were it not that one thing is helping them along in their journey; and this thing is the rain.

Many people do not know or never think of how the face of the land is being changed by the unceasing, quiet action which we have described, but everyone has seen how the rain washes the land away. On some summer's day after a heavy shower let us take a walk out into the country. Everywhere we see little rivulets of running water, and this water is muddy, that is, it is filled with little particles of earth which the water is carrying along. If we place a panful of this water on a stove and heat it until the water has all dried away we will find that it leaves a layer of mud or earth behind. If we had let the water alone, it would have carried this earth to a greater or less distance away, but when it stopped running, or came to rest, the earth would have settled down and come to rest too. In this way before we disturbed it the earth was perhaps being carried to some nearby marsh, or to some lake, or perhaps our little rivulet was carrying it to a larger stream, and from there it might have been swept into a real river, and have come to rest at last on the bottom of the sea.

The grass in the meadows and the trees of forests protect the earth very much and largely prevent the water from washing it away. But if on our walk we come to any little hill which is bare of grass, or if on a hillside we see a ploughed field, we at once see what a great deal of change the rain has made. There we see deep gullies, made by water out of which all of the earth has been washed, and perhaps these gullies are so large that the earth washed away from them would have made many hundreds of wagon loads. In another place we come to a deep ravine in which there is usually no water but which has been hollowed out by many rains, and we find by calculation that many thousand wagon loads of earth would be required to fill the ravine again.

And so each rain washes more and more land away from high places and carries it down to fill up low places. Readers who live in a mountainous country have always spread out before them a beautifully clear record of what the rain is doing. On the top of a high mountain ridge they will find nothing but hard, bare rock, which if the mountain is a very old one may be a part of the old, old crust that covered our cooling earth in the very beginning. As they climb down the mountain side, they soon come to great, irregular stones which have fallen from the solid rock above, and these may extend for many miles down the mountain and make the climbing very difficult indeed. At first almost no earth at all is seen. There is nothing but rocks piled on top of one another: nearly all of the smaller particles have been washed farther down the mountain side by rains.

As we go farther down the mountain we find more and more earth, and here the trees and plants are beginning to appear, and by their roots they are protecting much of the earth and keeping it from being washed away still farther. But yet by far the greater part of the little particles into which the rocks above have been broken have been carried into the valley far below. As we approach this valley we find a much greater depth of soil beneath our feet. The farther we go from the foot of the mountain the fewer stones we see, and what stones there are, are more smooth and rounded. And this tells us clearly of the ages that have passed since they first began their slow journey downward.

If we should drill a well at the very lowest part of the valley we might find that the soil here was many hundreds of feet deep. It has all been slowly worn away from the rocks above and then washed down by the rains, although mixed with the fine little rock particles we would also find the remains of trees and other plants, which, when the soil had been provided for them, had grown and died and decayed for many generations. And if we drilled deep enough we would find that underlying the whole there was the same solid rock of which the mountain ridge itself is made.

WHAT A GREAT RIVER IS DOING.

Whenever we see running water that is muddy we know that it is at its work of carrying little particles of earth away. And just as we see this happening in every little gully or rivulet by the roadside, so we know all the great rivers of the world are carrying the land away too, and emptying it onto the floors of the sea. The waters of the world are great architects which are ever molding the surface of the earth into a new form. But except for an occasional storm or cloudburst, their action is so gentle that it is hard for us to realize what great changes they really bring about. And yet, when we think of it, we know that a wonderful amount of water falls from the clouds upon us. If all the rain which falls during a single year should come down at once, it would cover the ground with water to a depth of forty inches in Pennsylvania, to a depth of fifty inches in Oregon and Florida, and it would cover the whole central part of the United States with a lake more than thirty inches deep.

The rains of the Central United States, instead of gathering together into one big lake, gradually flow into the Mississippi, and they carry much land with them as they go. By carefully studying the water of this great river, it has been found that every year it carries down more than seven millions of tons of land into the Gulf of Mexico. If this great quantity of land were placed in one pile, it would form a mass one mile square and more than three hundred feet high.

Very much of this land is carried out into the Gulf of Mexico and at last comes to rest at the bottom of the sea, but the river is all the time piling much of it up about its mouth and so the State of Louisiana is growing larger and larger. If you look on the map, you will find that the city of Baton Rouge lies far up in the State, more than two hundred miles from the Gulf of Mexico. One hundred and twenty thousand years ago the Mississippi River ended here; just at this place it flowed into the waters of the Gulf. But year after year it kept pouring out the earth which had been washed into it by all the little streams along its great course, until at last it built up the large area of solid land which we see today.

In the course of each five thousand years this great river carries enough land to the Gulf of Mexico to cover the whole central part of the United States a little more than one foot deep. In one hundred and twenty thousand years it must therefore have washed this part of our country away to a depth of twenty-four feet. Yet the action of some other rivers is very much faster than this. All over the whole world, the rivers are washing about six hundred tons of land away each year from every square mile of the earth's surface and carrying it down to the sea. And so we see that they must indeed have wonderfully changed the face of our countries during the past ages, and that these changes will continue during the ages of the future. Since the mountains of the eastern United States first appeared, masses of rock from one to four miles thick have been worn from them, and from the surface of all the lands of the earth at least many thousands of feet have been worn away by the waters of our air.

HOW THE SEA WEARS LAND AWAY.

We now come to the most striking and interesting of all the great forces which are changing the surface of the world; and this is the action of the sea. Nearly two-thirds of our earth is covered by the water of the oceans, whose waves continually wash and beat against the thousands upon thousands of miles of shore which border all the great continents and islands, and ceaslessly and steadily it is wearing them away. It is true that the sea makes some lands larger, but it does this by washing upon them a part of the rocks or earth which it has torn from some other shore and ground into a fine sand by its wonderful power. But by far the greater part of the land which it wears away it buries far beneath its own waters, and so, little by little, it is steadily making the continents smaller.

We may wonder whether the land will not in time be all buried under the sea, and our world become covered by nothing but one great ocean. It may seem to us that the sea is forever battling against the land and always winning the victory; that at last it will have destroyed all the solid ground which now rises above it and that no land animals or plants can then live on the earth. But this is not true. It is not true that the sea is waging a war against the land and the living things on it; it is not really their enemy, but their friend. For we will learn in a later chapter that when it robs us of miles upon miles of rock and earth, it is only to form out of them new rocks and a new land and to prepare them in a most wonderful way to become a home for the living things which shall come after us. Deep under the sea, new lands are ever slowly forming; it was in this marvelous laboratory that the continents of the earth were made. But the story of the wonderful things which happen to the rocks and earth which the sea swallows up is to be told in another part of this book: here we tell only of how its waves are forever destroying the land,—and this is a most interesting story too.

Along much of the northern shore of the United States the coast is formed of almost solid rock. This may be sculptured into great cliffs which rise straight out of the water and whose faces are as steep as the sides of a house. The scenery along such rocky shores is often most wild and beautiful, but of even more interest to the student than their beauty are the evidences which they show him on every hand of the wonderful power of the sea. Here there is as clearly written as if it were in a book the story of the lands' destruction, and as we walk along the ever-moving waters we are told over and over again of exactly what changes they have been bringing about during the years that are past. We see the little waves ceaselessly dashing against the rocks, and twice each day, as the tide rises and the water deepens, great breakers roll in and hurl hundreds and thousands of tons of water against them, over and over again.

But when there is a storm at sea then indeed the evidence of its measureless power is greatest and most impressive. One after another, the great waves roll in, striking the rock such blows that the whole ground trembles. A long distance away the roar of the waters can be heard, and beside this deep roar there is a continual crashing, made by the stones swept forward by the water as they are dashed against the face of the cliff.

On nearly all such rocky shores we will find, if we examine them carefully, that the rocks are not all of equal hardness. In some places there may be upright crevices of softer rocks which are called "Dikes"; in others, we find that the softer rocks are imbedded in the harder ones in masses of all kinds of shapes. As the sea wears away the softer rocks first, such coasts come at last to take the most irregular and fantastic forms. Sometimes a single great pinnacle is left standing above the waters, far out from the shore, all the softer rocks which were formerly around it having been worn away. These striking monuments are known as Pinnacled Rocks, or Pulpit Rocks, and the sailors sometimes call them "Devil's Thumbs."

In other places a deep hole may have been worn into the cliff; the rushing waters wear this larger and larger, but they wear the front part of it away most rapidly so that in time it becomes shaped like a large funnel. At last the smaller end of the funnel may become extended all the way through the cliff to its upper surface; if we walked along the top of the cliff, we would find a hole there through which, if it were large enough, we might descend through an ever widening cavern to the sea. Now whenever a heavy storm arises, the waves are driven into this cavern, sweep toward its smaller end with ever increasing speed, and at last rush out into the air in a great column of spray and foam. These interesting formations are called ''Spouting Horns.''

Unless the cliff is made out of a fiery rock which is very tough and uniform indeed, we will find that there are many cracks and crevices running through it. The sea will force its way into these and wear them away first; the water rushing into the now widened cracks will often force out great masses of rock which then fall to the bottom of the cliff. The breaking off of large rocks in this way is also much helped by the action of frost. And if the cliff is a high one, the sea may eat farther and farther into its base, until at last the overhanging top falls in one great ruin into the water below.

This shows us why the shores along rocky coasts are usually so very rough and stony. And we would find that for some distance out from the land the bottom of the sea was covered with such large, rough rocks too. Near such cliffs we often find almost no sand or fine earth at all; the sea has washed it all away, and only the heavy stones are left. But these stones are being worn into a fine sand, and in ages past thousands of times as many great rocks as we see around us have been slowly worn to pieces and carried away by the sea. What becomes of them at last? In the first part of this article we have said that the greater part will come to rest on the bed of the ocean, there to go through a wonderful change, but some may again be given back to our land and form a shore very different from the rough, rocky coast from which it came at first.

HOW SAND BEACHES ARE MADE BY THE SEA.

We have seen how our rocky cliffs may be broken up into great rough stones, how the waves of the sea may slowly wear these stones away, and how during great storms even very large rocks may be drawn away from the shore to a considerable distance under the water. Now it is almost always the case that if we go a little way out from the land we find a current, or river of water in the ocean, which hurries us along in nearly the direction of the coast itself. And so, when the sand and stones reach this current, they may be carried for many miles up or down the coast, and at last they may be washed ashore again in some far different place.

When the current sets in very near to the land, the fragments of our cliff are swept along very near the shore line, the largest rocks nearest the shore, the pebbles farther away, and much of the fine sand very far out in the deep water. Very near the cliff there may be a ledge or point of land which checks the rapidity of the current, so that it is no longer able to sweep the stones and larger pebbles along. And so these are dropped here; the great stones are here rolled backward and forward by the heavy storms, and both they and the pebbles pound against one another and grind one another away into smaller particles which are again swept into the current to enter upon a longer journey. At last they may come to rest on the bottom of the sea, or they may be washed up on some far distant shore where the action of the wind steadily moves them inland, so that a new country is built from them.

The carrying power of the current and the wearing action of the waves is sometimes very strikingly shown when a ship loaded with bricks, or coal, or other hard material is cast away. A few months after the ship has broken to pieces, if we walk along the shore, we find the fragments cast up for miles in the direction in which the current is running. Those which have been washed onto a stony, pebbly shore are many of them already nearly worn away, but those which have come to rest on a smooth, sandy beach may endure for many years before the sea finally destroys them.

One of the most interesting little trips which we can take is a walk along the shore of any rocky coast. Here we see a rocky cliff, with the great, irregular, jagged stones which have fallen from it. A greater or less distance away we see a point of land running out to sea, and when we come to the other side of this we find the shore strewn with great numbers of smoother, rounded rocks, attesting clearly how the waves are wearing them away. These rounded rocks have, of course, come from the cliff; through storm after storm they have been slowly moved along until the force of the current, checked by the point of land, could move them no farther. Here they are being slowly ground into finer material.

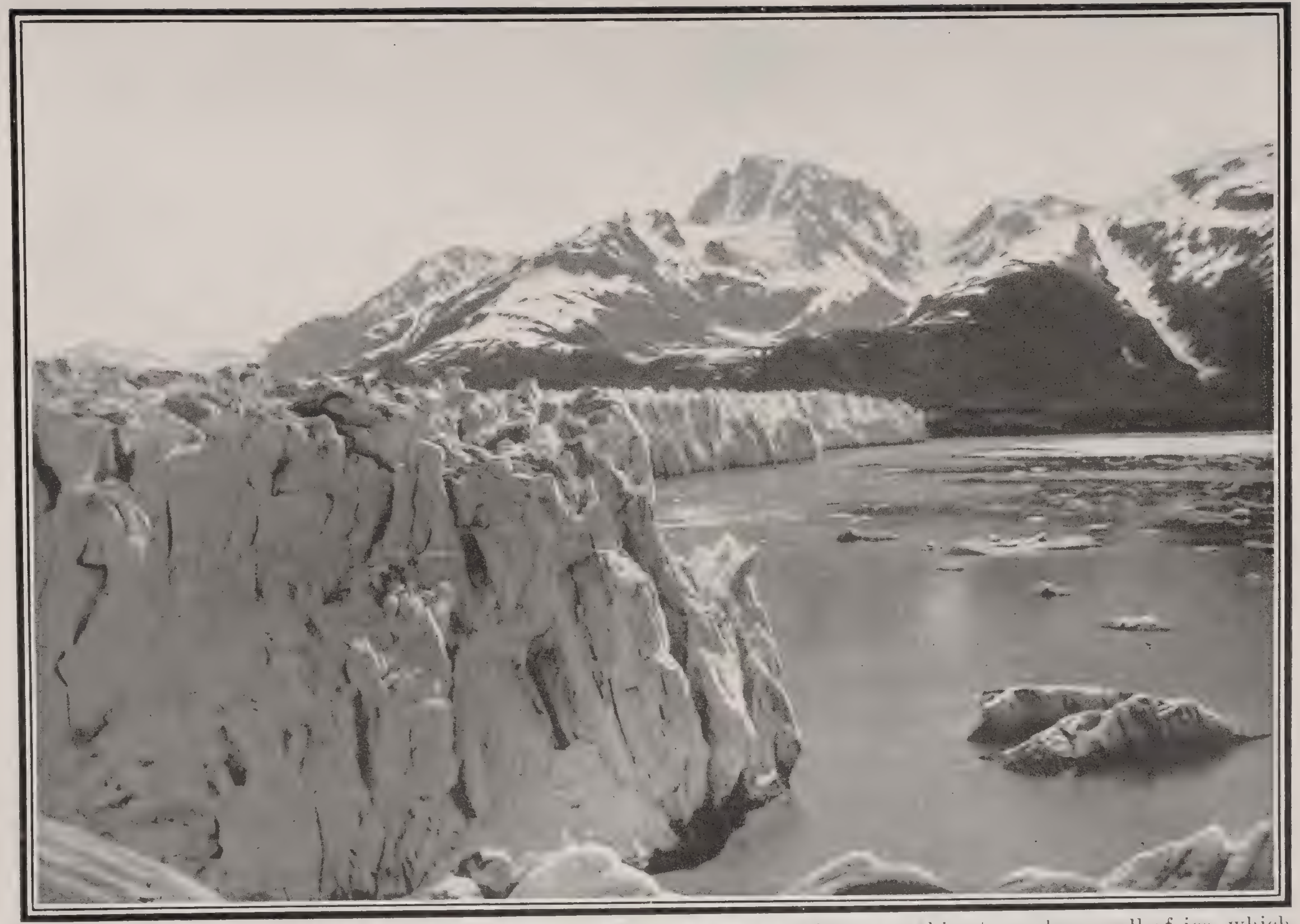
Let us suppose that there is a long, flat shore beyond the point where these great stones are. As we walk along it we find the stones getting smaller and smaller; after we have walked a mile or two, we may find none larger than an orange, and these have all become very smooth and highly polished during their journey from the distant cliff. And as we go still farther we come to a shore on which the largest stones are only very hard and smooth little pebbles, while farther still we find nothing but the finest sand.

Here is the end of the rocks of our great cliff. The pleasant, sandy beach on which we stand has all been formed by the grinding away of the far distant rocks in the mighty mill of the sea. But we must not forget that only a very little of our cliff has been washed ashore here. A little part of it near the inner edge of the current has been thus given back to the land, but by far the greater part has been swept away and is now lying at the bottom of the ocean.

HOW GLACIERS ARE FORMED AND HOW THEY FLOW.

We have now told about the principal ways in which our lands are ever being destroyed. It is true that there are other ways than these. For instance, the winds of the desert, sweeping great clouds of sand along with them, are seen in time to wear away the hardest rocks. In these places too, the sudden changes of temperature from intensely hot days to cooler nights help to break the rocks to pieces. And in countries near the sea, whenever material has been broken small enough, it may be blown away from the shore by every strong land breeze and fall so far out on the surface of the water that it is never recovered by the land again. Along the seashore there are even strange little animals which actually bore into the hardest rocks and cause them to crumble to pieces. But all of these things, and many others, have very little effect in changing our world in comparison with those which we have told about.

There is, however, one great source of change, which although it is doing but little now, was once one of the most powerful and widespread of all. And this source is found in the great sheets of ice called Glaciers. In the present age these great masses of slowly moving ice cover only a small part of the land; the largest sheets of all are found near the South Pole and on the continent of Greenland; the latter country, except for a very narrow strip near its coast, being entirely covered by a vast sheet more than half a mile thick. Among the mountains of Alaska, Switzerland, and other countries there are great ice



MUIR GLACIER, ALASKA.—Nothing could be more awe-inspiring than this stupendous wall of ice, which is 300 feet above the waves in Muir Bay and 400 feet below them.

streams, but grand and impressive as these stupendous frozen rivers appear to us, they are doing very much less to change our world than even the gently falling rain.

This is because the glaciers now cover only a very small part of the lands of our earth. But there was a time when all of North America well down into the United States was deeply buried under the ice, and when nearly all of Europe was covered so deeply that only the highest peaks rose above the ice sheet. And this wonderful sea of ice withdrew toward the north, and then advanced and covered the lands again many times, rounding off the hills, scouring away the soil, and carrying vast quantities of rock and earth to far distant countries or even far out into the sea itself. That we may better understand the changes which these great glaciers have made in our world, we will study for a little while the much smaller glaciers which may be found here today.

A glacier is a great river or ocean of ice, at least one end of which must lie in a place where the falling snows keep getting deeper and deeper without ever all melting away. Many mountains are so high that their tops are far above the region of perpetual snow. In these high, cold regions each snow storm adds its snow to the great depth which has fallen before, and as the snow grows deeper it becomes firmly pressed together by its own great weight until at last all the lower parts of its mass are compacted into solid ice. That this may happen it is necessary that the part of the mountain on which the snow is resting shall not be too steep, for otherwise the deepening snow will from time to time rush down the mountain side in avalanches.

So we see that in order that an ice river may be formed, its upper end must be in a place where snow falls continually, year after year, and where it can grow ever deeper without being disturbed. And we see that all the lower part of this great mass of snow will be changed by the pressure into solid ice. Now this ice under the great pressure upon it, and because it is on sloping ground, will begin to move downward, or flow, just as water flows down hill, but the ice will move ever so much more slowly than water. Its motion will take it down the steepest places, and so it will naturally enter the deep valleys or gorges and flow down these toward the base of the mountain. When its lower end reaches the lower lands where the weather is warmer it will melt, but the melting ice at the lower end will be continually replaced by the colder ice behind it, and the whole ice river will be continually fed by the new ice which is ever forming at its upper end. Thus, although its lower end is always melting away, the great ice mass will continue to flow.

The center of a flowing glacier moves faster than its sides and the ice of its surface moves faster than that which is lower down. This is because the sides and bottom of it scrape against its banks. And because the sides are held back, the ice stream is often broken into great cracks called Crevasses along its edge. Other crevasses are formed if the slope of the ground over which the glacier is flowing changes suddenly—great cracks which go straight down between the two walls of bluish, transparent ice for perhaps many hundreds of feet. The most rapidly moving parts of the glaciers of the Alps flow from a few inches to four or five feet a day; there is a glacier in Alaska which has been known to move seventy feet a day. So we see that the downward flow of glaciers is very slow.

The great ice sheet which covers Greenland is formed in very much the same way as a far smaller mountain glacier. This wonderful frozen ocean is continually fed by the snows of the far northern regions and it is ever moving slowly southward, hiding the whole country under a deep ice plain. In some places its southern edge ends in a great wall, the ice of whose surface is ever melting, but which is renewed as it melts by the new ice continually pushed forward from behind it. In other places the thick ice sheet pushes out into the sea, where great portions of it are broken off and floated away by the lifting power of the water. These broken pieces of the ice sheet are called Icebergs. They are sometimes of such enormous size that they seem to be true ice mountains. Yet when ice floats in water it sinks so deeply that the part hidden below the water is eight times as large as the part above. So that even the enormously large icebergs are really nine times larger than they appear to be. These great masses of floating ice sometimes travel thousands of miles from the glacier where they were first formed, before the heat of the warmer latitudes can melt them. As they are so cold they are often surrounded by a heavy fog, and so they become a source of very great danger to ships.

HOW GLACIERS CHANGE THE FORM OF THE LAND.

When so great an ice sheet flows over a country, burying it thousands of feet deep under an enormously heavy mass of slowly moving ice, it must surely leave many evidences of its visit. And these are so strange, so very unlike any changes that are ever brought about by anything else on our world, that we can tell with absolute sureness where the ice has been, how it moved, and what remarkable effects it has produced. No land can possibly go through so wonderful an experience without the traces of its strange existence for so many centuries under the ice being left about us on every hand.

In the first place, every glacier moves a great amount of earth and rock from one part of the world to another. When a part of the ice sheet reaches a mountainous country and the ice is forced through the deep valleys, very much material will be scraped away from the sides of these valleys and other material will fall on the glacier from above. Much of this will fall down the deep crevasses, which are always near the edges of glaciers, and so become buried deep in the ice, while much of the rest will simply ride on or near the top, just as stones and earth might float down a river on a raft. And in the same way the slowly moving glacier will press around and carry along with itself very much of the material at the bottom of the valley, so much so, that valleys down which early glaciers have passed are changed from a V-shape to a flat and rounded U-shape. They have been carved out, and all their material which was cut away has been carried along by the glacier itself.

We therefore clearly see that after a glacier has been moving for some distance it will have gathered up an immense amount of earth and stones, and these will be found not only at the top and at the bottom of the glacier but more or less scattered throughout the whole mass of ice. Now let us think of what the conditions are at the very bottom of the glacier, where the ice rests on the ground. Here are a great quantity of stones and rock fragments, packed very firmly into the lower surface; far above them and pressing down upon them there are thousands upon thousands of tons of ice. It is easy for us to see that so enormous a mass, whose lower surface is so rough and hard, will be able to scrape away whatever is in its path.

We have seen that the soil of our earth is made out of little fine particles of rock which have been slowly worn away from the great rock masses, and that mixed with these are the remains of many generations of trees and other plants which began to grow as soon as the rocks were sufficiently broken up to sustain them. And we have learned how the rains wash this soil down into the valleys, but that a short distance below the surface of the soil itself there is always the solid rock on which it rests. Now the glaciers often scrape away every bit of this soil, all the way down to the solid rock. And the rock itself is grooved and scored by the rough stones which are in the bottom of the glacier. It is as if an enormous carpenter's plane, with a very irregular and notched blade, had been pushed over the hard rock, covering it with grooves and scratches. The grooves all extend in the same direction on any one rock; they tell us at a glance in what direction the glacier which made them was moving.

Let us now imagine ourselves at the front end of the great ice sheet, at the place where the glacier has pushed itself so far forward into a warmer country that its face is continually melting away. This front edge, or ''Glacier Wall,'' may be many thousands of miles long, but every part of it must necessarily be at a place where the weather is just warm enough to melt the ice away exactly as fast as it flows down. If the weather should grow warmer, the ice could not come fast enough to take the place of that which melted away, and the wall would move backward into cooler regions; if the weather should grow cooler the front edge of the ice sheet would move farther south.

Mile after mile of ice moves slowly down toward the front edge of the ice sheet, and is melted away. And as it melts, all the rock masses, and stones, and earth which it has gathered on its long journey fall to the ground at its foot, and there build up a huge, long pile, or hill, of all kinds of materials. This long mass of glacier material is called a Terminal Moraine. When we see a terminal moraine we can not possibly make the mistake of supposing that it has been built up by anything except a melting glacier. For, as we have seen, whenever land is gathered together by the action of the rain and frost, or by flowing rivers, or by the sea, it is built up in a certain orderly way. We can tell how it came to be formed, and we can often go to nearby rocks from which it has been made, and see before us every step of its development. But in a terminal moraine all is very different. Here are great rough rocks, jagged stones, smooth stones, sand and earth, all mixed together in an irregular heap. And the materials may be of the most widely different kinds. Fiery and layer rocks, hard and soft rocks, and all imaginable kinds of soils have been collected by the glacier in its journey, to be at last all piled together, far away from where they were first formed.

As the weather changes and the glacier wall moves backward or forward, the positions of the terminal moraines change too. Many great ridges are thus often found, all made by the same glacier. And when the weather begins to grow permanently warmer, year after year, the face of the glacier will steadily move backward, scattering its material quite evenly over the country as it goes. At the same time its sides will be melting away in the great valleys, and long ridges of material will be left here which are quite similar to the terminal moraine. By carefully studying all such evidences of the motions of the glaciers of the past, it has been found that there were no less than five ages of ice. That the great ice sheet flowed over our country and then melted away; that our climate remained warm and pleasant for a time, but afterward the ice again overflowed it, and that this was repeated no less than five times.

AMERICA DURING THE ICE AGE.

We will now tell of the wonderful and interesting things that happened in America when, over and over again, it was buried deep under the ice. All that we will tell about has been learned by a careful study of the deep scratches and grooves which are found on the rocks, of the great moraines which were left behind, and by the changes, often very great ones, which were made in the whole country. If we had space enough it would be most interesting to tell of the effects of the ages of ice in other countries too; of how an ice wall stretched two thousand miles from the south of Ireland to northern Russia, and of how all the great continent of Asia from the Himalaya Mountains to the Behring Sea was also buried deep under the ice. Great changes have been made in all of these countries, some of them even more striking than any which occurred in the United States, but to learn about them the reader must consult larger books than this one.

Before the coming of the ice age, the climate of the United States was warmer and much damper than it is now. Great mastodons, elephants, bisons, sabre-toothed tigers, bears, and other animals wandered over the land, while in the forests we would have met with enormous sloths as large as elephants, and strange, giant armadillos. Little by little the weather grew colder, and the host of wonderful animals had year by year to move nearer the equator. The plants and trees which could no longer stand the cold climate slowly spread southward too, and their places were taken by the small, hardy, little arctic plants which can live at the very edge of the ice.

As we have before explained, the great ice sheet advanced and then drew back again no less than five times. During the centuries when it was slowly receding the weather was steadily growing warmer, and then many of the animals and plants moved northward again. It is very interesting to know that many of the little arctic plants which are growing today on the tops of the highest mountains were actually first brought there by the glaciers of the ice age. In no other way could they have passed all the warm country which lies between their cold northern home and their new homes on the cold mountain tops.

Five times America changed from a warm land to arctic cold, and each time the plants and animals which might have been found here changed too. The plants nearly all lived through the violent changes, moving slowly southward and then northward again as it became necessary, but in Europe a great many disappeared. This was because the high Alps and Pyrenees prevented their southward motion and they were killed. We therefore find many trees in American forests which are never seen growing in Europe although the climate and soil there are now well suited for them. The trees in America were saved because there was an open country before them, across which they could slowly spread to the warmer lands of the South where they could remain until the time of cold was over.

But very many of the animals, and nearly all of the very large ones, became extinct during the ice ages, and vanished from our earth forever. The rhinoceros, elephant, hippopotamus, and many smaller animals still live, but the most wonderful and gigantic of the creatures will never again be seen alive. Yet, as we will learn later, their enormous bones, and even whole skeletons are still found in many places, and some years ago a great mammoth or hairy elephant was found frozen in the soil of Siberia. As long as it remained frozen all of its great body with the skin and hair upon it was perfectly preserved, so that those who found it looked for a short time upon this great creature exactly as it was when it walked upon the earth thousands of years ago.

It is probable that many of the great animals disappeared after the ice age, because our earth became so much cooler and the air so much dryer. The few that still exist are found in the tropical regions; that is, in the very hottest parts of our earth.

We have seen how the ice of a glacier always flows from higher land to lower land. During the ice age there were three high places north of our country, and from these regions the ice flowed outward in every direction. One of them was on the highlands of Labrador, and the ice from this covered New England and the Middle States and spread west all the way to the Mississippi River. A second was on the west shore of Hudson Bay, and this glacier pushed downward as far south as Iowa and westward to the Rocky Mountains. And lastly, there was a great glacier center north of the State of Washington, in British Columbia. Besides these three great centers from which the ice sheets moved, there were very many smaller glaciers moving down the sides of the mountains and covering parts of our country with ice which were not reached by the greater ice sheets.

In its different advances and retreats, the great ice sheets covered the northern part of the United States with many new features, but the most striking and interesting of these is the great Terminal Moraine, whose position marks the extreme southern line to which the ice was pushed. This extends the length of Long Island, then runs to the eastern end of Lake Erie, then turns south-westward to southern Illinois, then westward to Kansas, then through Nebraska, South and North Dakota and Montana, into Canada, and finally stretches north-westward to the Arctic Sea. North of this great moraine the mountains and hills have been rounded by the ice, except that here and there are peaks so high that the ice did not cover them, and so could not wear their tops away. Here are also a very great many lakes, made in some places by water collecting in the hollows from which the ice scraped the soil away, and in others because the moraine there made a dam. Toward the end of the ice age, a very large lake was made in the north. This has been named Lake Agassiz, but it is a lake no longer. Long before the coming of the white man to America its waters had all drained away.

Thus we see that the coming of a great ice sheet will scrape all the soil away from some places, to carry it off and pile it up in some other, far distant places;

that it will form great lakes, and change the course of rivers, and that it will round off mountains and hills and make the whole country lower and less rugged than it was before. As it had much to do with changing the lands around us, its coming has much effect even upon our lives today, although the last of the ice withdrew to the north thirty, or perhaps even fifty thousand years ago.

CHAPTER XXIV.

How Lands Are Built Up.

THE SHAPE OF THE LANDS WHICH ARE UNDER THE SEA.

IN the last chapter we saw how all the great rivers of the world are steadily carrying our land away and burying it in the ocean, and how in past times the great ice sheet scraped away and carried off a great deal of land at all places where its ice wall pushed out into the sea. And we learned how the sea is ever wearing away even the hardest rocks and grinding them, first into stones, and then into smaller, rounder stones or pebbles, and at last into a fine sand, which nearly all disappears into the depths of the ocean.

Is this all we can learn about our land which is lost? Must we say of the thousands and millions of tons that are washed into the sea, only that it is gone and we do not know what becomes of it? The sea itself is swarming with living things; it has its valleys and mountains, and even its volcanoes, and all this great sea country, though buried deep under the water, is a no less interesting land than our own. Like our own land, it is continually changing; but instead of forever wearing away, it is forever being built up.

Even if we knew that we could never visit that strange country and walk about in it, the knowledge of its changes and growth, so unlike those we see in our own land, would surely be most interesting to us. But it becomes of far greater interest when we learn, as we will soon do, that the sea country of today is a land country tomorrow; that nearly every part of the great continents of the world have been sea countries at different times, and that the depths of the ocean are the great workshop where the rocks of the land were formed. And new lands are forming there even now, which without doubt will be lifted above the waters in the remote ages of the future.

Let us first learn what has been found out about the shape of the bottom of the sea. By sailing back and forth over the oceans in ships, and letting down long lines to find how deep the water is in different places, we can find out just what the shape of their bottoms is, and then we can picture to ourselves just how they would look to us if the water could all be drawn away.

As soon as men began to do this, they at once found out one very interesting thing, and that is that the bottoms of the great oceans are not at all flat, like floors. The water is wonderfully deep in some places and shallow in others; in fact, the ocean bottoms have very deep valleys and high mountains and great level plains on them just as the continents do. Yet generally the bottom of the sea is more regular than the surface of the land. It extends for immense distances in gentle undulations and slopes, so that vast plains and plateaus are more common there than in the dry regions of the earth.

Running nearly the length of the Atlantic Ocean there is a great dividing ridge, which separates it into two "Deeps," or "Troughs," an eastern one and a western one. The very tops of this great mountain ridge are more than a mile under water, while in parts of the deep valleys on the two sides of it there are places more than five miles below the surface of the ocean. This is indeed a marvelously great depth. Could we stand there, the miles of heavy water above us would press with a force of more than seven hundred tons upon each square foot of our bodies. This enormous pressure would instantly kill us. For a long time men believed that there could be no living things in these great sea depths, but when they learned how to draw the material which is there all the way up to the surface, they found that it was peopled with most strange and wonderful forms of life.

In the Pacific Ocean there is no one, long, dividing ridge as there is in the Atlantic, but there are many shorter mountain ranges and some very high mountain peaks and many volcanoes, all buried deep under the water. And in the southern part of this ocean, east of Australia and a little north of New Zealand, there is the very deepest water which has ever been found on our earth. The ocean here is 30,930 feet deep. If the very highest mountain in the whole world could be put into this great hole, it would be all hidden under the water.

A SHELF OF LAND WHICH IS UNDER THE SEA.

If we could walk far out over the bottom of the sea, we would find that the water was wonderfully deep. Here and there, after climbing up a high plateau or mountain ridge, we might rise near the surface, but there would be very few places in the whole sea country where we would find ourselves less than a quarter of a mile below the waves. But it is only far out from land that the water is so deep. Whenever in our travels we came within fifty or one hundred miles of a coast, we would find that the floor of the sea rose steeply upward. Climbing up the steep slopes, we would come to a gently sloping plain, over which we would have to walk for many miles before we reached the shore itself.

Along the coasts of nearly all countries the land under the sea slopes downward very gently indeed. Ships are sometimes cast away and sink to the bottom many miles from shore, and yet though they are so far out in the ocean, their masts may remain in sight above the water. If a giant five hundred feet tall should wade out into the water almost anywhere on the eastern shore of North or South America, he would have to wade a long distance before he came to water which was over his head. For the first three or four miles it would hardly be as deep as his knees; after he had waded forty or fifty miles, it might come up to his waist, but by and by, when he had gotten perhaps one hundred miles from the shore, it would suddenly begin to grow very much deeper and he would have to begin to swim.

This long, gentle slope which lies along our shores is called the Continental Shelf, because if we make a model of the surface of the earth from which the water of the oceans is left out, it will be seen extending like a shelf around the deeper ocean basins. The water above this shelf is so shallow that much sunlight can shine through it, and many seaweeds therefore grow upon it. All kinds of sea animals live at different depths on the shelf, and the many forms of life furnish a plentiful supply of food for fishes of different kinds. The best fishing grounds are therefore along and near this part of the sea; the "Banks" of Newfoundland, and of other countries, are merely shallow parts of the great continental shelf.

We know how on the land some plants and animals live in low, wet valleys, while others are found on the dry hills and mountain sides, and how at the very tops of our highest mountains only certain little mosses and other arctic plants can grow. And all this is even more true of the sea. Nearly all the sea plants and animals can only live in a little zone or belt where the water is just deep enough for them but not too deep. This is because, in the first place, the deeper we go down the more water there will be above us and the harder it will press upon us. We have already seen what an enormous weight of water is supported by the very lowest parts of the ocean bed. And in the second place, the deeper we go under the water the darker it gets. From the most profound depths of the ocean, not a trace of any sunlight can ever be seen;

it is a region which is forever darker than the blackest midnight. Yet even here there are living things. And it is most wonderful that many of them shine with a strange, phosphorescent light, just as fire-flies and glow-worms do: their own dim light is the only light they ever see.

The continental shelf and the waters above it are, in general, swarming with life. Farther out under the ocean, new and quite different kinds of life are found, each different kind of animal or plant always keeping in its own belt or zone. And almost throughout the whole ocean at and near its surface, there are countless myriads of very little creatures which exist in such wonderfully great numbers that certain parts of the ocean floor are deeply covered with the remains of them. All these things which we have learned will help us very much to understand what is soon to be said of what is going on at the bottom of the sea.

Although nearly every land of the world is bordered by the great continental shelf, yet there are some places where the continents plunge at once under the waters to an immense depth. This happens along the west coasts of Mexico, South America, and Africa, and in a very few other places. Such great depths are almost always found where a very high range of land mountains lies closely along the sea. The reason why they occur in such places will be explained in a later chapter.

HOW CERTAIN LITTLE ANIMALS BUILD UP THE FLOOR OF THE SEA.

Every one knows how clear and transparent pure water is, and every one has seen how very different it comes to look when it has stood for some time in some neglected place where it has collected into a stagnant little pool or marsh. Then it becomes covered with a green or brownish scum; it feels slimy when we put our hand in it, and it may even smell disagreeably, so that we know at once, even if no one has ever told us so, that it is no longer fit for us to drink.

Certainly, nothing could look much less interesting than such a little pond of greenish, stagnant water. But if we put a few drops of it under a microscope we instantly see that it is a whole little world, swarming with all kinds of life. The unattractive, greenish scum is revealed to us as a wilderness of beautiful and different kinds of little plants, all growing together, while living with these and swimming among them in every direction are hosts of the most curious little animals imaginable. All these wonderful varieties of life are born and live and die in one little pond of water. If we could be made small enough, we might wander for years in this pond-world, finding so much that was new to interest us that we might be sorry when the time came for us to grow big and come back to our wonderfully much larger world again.

Although we can not visit this very little world in this way, yet with the microscope we can watch what is going on there. And what is seen is found so interesting that men spend their whole lives studying its wonderfully small forms of animal and plant life. In this book we have learned a little about the marvelous growth of great worlds and suns; we are now learning about what has happened to our own very little world, and if we wished we might find many books about the wonderful forms of life and growth in something so small as only a few drops of water. Wherever we look, whether at the very smallest things we can see or at the very largest, we find like sources of wonder and absorbing interest. Everything that is, is the work of the same hand; whatever part we study, we never come to the end of all it has to tell us. All our lives long we may continually be led to a knowledge of more that is wonderful and new to us.

Just as little ponds of fresh water are swarming with life, so the waters of the sea are filled with countless millions of little animals and plants. In some parts the waters are principally filled with one kind of living creatures, and in other regions they are filled with others. And these wonderfully small little specks of living things exist in such marvelous numbers that they are very important builders of our world.

All over the oceans, except in the Polar zones, where the waters are too cold for them, we find the most important builder of all. This is a round, very little speck of living matter which is actually an animal and which has been named Globigerina, or the "Globe Bearer." Though it is so very small, it has a most delicate and beautiful little shell, and this shell is made out of *lime,* just as most larger shells and the bones of our bodies are made out of lime too. The myriads of globigerinas grow in the sea, and they die and their shells sink to the bottom. And so a layer of these very little lime shells is found on the floor of the ocean. And as year after year passes away the layer grows thicker and thicker. Men have found that nearly fifty millions of square miles of the bottom of the ocean are covered with a layer of lime which was made in this way.

Nearly all of the larger sea shells are made out of lime too, and when the animals which live in these shells die, this lime is also added to the bottom of the ocean. Sometimes these larger shells keep gathering there deeper and deeper almost without being broken at all, just as if you should empty one large basket full of shells after another evenly over a floor until you had it deeply covered. But sometimes they are first washed onto a beach and there all ground to pieces before they come to rest at last at the bottom of the ocean.

The two most common kinds of rocks there are, are sandstone and limestone rocks. We have already learned part of the history of a piece of sandstone;

how far earlier rocks were ground into little particles of sand by the rain and the sea, how they were then spread out over a part of the ocean floor in a layer, and how this layer became cemented together and hardened into a new rock which we call sandstone. So that the sandstone which is found on our land was once under the sea.

In just the same way the layers of lime which are on the floors of the ocean slowly become rock, and afterward they may be lifted above the waters to become a part of our solid land. And as the lime is laid down in layers, so limestone, like sandstone, is a layer rock. In some places there are great thick beds of a soft and powdery limestone which is called Chalk. Along the straits of Dover, and in other places, these beds have been gradually cut into by the sea, until they now stand up from the shore in high, steep, chalk cliffs. And if we examine a little piece of this chalk with a microscope, we see that each of its little grains is the shell of a very minute sea animal. The whole bed is nothing but an inconceivably great number of these shells which were pressed and cemented together ages ago, when they were at the bottom of the sea.

Other limestone rocks are even more interesting than these because they are nothing but a dense mass of all kinds of shells firmly cemented together, some of the shells being so large that we can easily handle and examine them without a microscope. It is most interesting to sit at our table with a large stone of this kind and to carefully separate each shell with a knife. We soon have the whole table top covered with a most interesting collection of shells, which once belonged to many different kinds of living creatures.

A great part of the United States is filled with limestone rock, but unfortunately in very much of it only a few shells or other remains can be found. This is either because the shells of which it was formed were all ground up by the sea before they hardened into rock, or else because after it was formed the rock was pressed or squeezed together so very hard that all traces of what it contained were destroyed. The rock called Marble is a kind of limestone in which all traces of separate little shells have been destroyed in this way. And sometimes the limestone rock is not pure. It may be partly made out of a hardened mud, or even out of sandstone and other things, simply because these things were washed out onto the bottom of the sea and mixed with the lime which was there before it had hardened into a rock.

WHAT BECOMES OF THE LAND WHICH IS WASHED AWAY.

We are now ready to take up the interesting story of all that happens to the great masses of land and rock that are washed into the sea. Let us begin by asking ourselves where it all goes to—whether we find that it is all mixed together everywhere in the sea country, or whether it is to some extent sorted out, one part of it coming to rest in one certain place and another part in another.

Only a few years ago, we could not have told where all of this land went. Men often wondered what there was in the very great depths of the ocean, but they had no way of finding out. But now they have learned how to let little instruments far down through three or four, or even five miles of water, and to lift a part of the sea bottom from such profound depths all the way to the surface. And they have explored a great part of the ocean floor in this way, not only finding what is there, but even measuring how cold the water is, and how dark it is at different depths, and what animals and plants can live there.

Along sandy or rocky shores we find that a wide strip of the sea bottom is almost nothing but sand, and we can generally see from what shore rocks the sand has been ground away. The sand belt may be many miles wide, especially if there are strong currents or out-draughts of water carrying it away from the shore. Along the coast where the water is very shallow we may find many pebbles, or even large boulders, but as we go outward into deeper water these get fewer and smaller, and the sand gets finer, until at last the sand bottom gradually changes into a mud bottom.

The mud of the ocean has much of it been carried away from the land by rivers, but much of it is the earth and soil which has been washed away from the land by the sea. The little mud particles which are carried by the water are very much smaller than the grains of sand. For this reason they are carried much farther away from the shore before they at last sink to the bottom. We can make this very clear by a simple little experiment. It is only necessary to stir some mud and some coarse sand together in a glass of water and then to set it away in a quiet place to "settle." Almost as soon as we stop stirring we see the sand beginning to fall to the bottom, but it will be many hours, and perhaps more than a day, before the mud comes to rest on the top of the sand, and the water above it grows clear.

And so, outside of the sand belt, we come to the mud belt. Sometimes a great river continually empties such great quantities of mud into the comparatively still waters of a sound or gulf that the whole bottom in such places is a mud bottom, all the way up to the shore; there may be other materials there too, but there is much more mud than anything else. This is the case in the Gulf of Mexico; nearly all the bottom of this gulf is covered with the mud which is brought down by the Mississippi River.

But the waters of rivers and of the sea not only wash the land away; they also *dissolve* parts of it, just as salt or sugar is dissolved by water when it is poured upon them. When material is dissolved in this way, it will usually never settle out of the water at all, no matter how long the water stands. We say that the waters of the ocean are ''salt''; they have a bitter taste and are not good to drink, and this is because so much land material is dissolved in them. In the present day all the rivers of the world and the action of the waves along all the coasts are forever dissolving part of their material, and in past ages when the waters of the sea were hot this dissolving went on much more quickly, not only on the land, but with the rocks which were at the bottom of the sea itself.

Some of the material from which rocks and lands are made dissolve very slowly in water, while others are absorbed very quickly. One of the things which dissolves most easily is lime. All of the really great caves of the world are in limestone rocks; the surface water began to work its way down through crevices in these rocks long ages ago, and it has been slowly dissolving the limestone wherever it touched it ever since, until at last great passages and caverns in the solid rock have been dissolved away.

And now we come to a most wonderful and interesting step in our world-building. If there were no living things in the ocean, nearly all of the lime and other materials which are *dissolved* away from the land would never be given back again. The waters of the sea would keep growing saltier and more bitter, and at last a great many of the materials of our rocks and lands, some of which are even necessary to life on our world, would become permanently dissolved in the sea. But this does not actually happen because it is prevented in a very wonderful way. Not only do many of the larger sea creatures absorb the lime from this water and build up their hard shells with it, but the countless myriads of little globigerinas and other minute animals are also reclaiming this dissolved lime to build up their little shells, which at last sink to the bottom of the ocean. And other minute animals and plants build up shells from other things which the waters of the sea have dissolved.

And so, on the deeper bottoms of the ocean, so far from shore that even the fine mud is but little of it carried, we find a layer of lime, nearly all of which has been rescued from the sea by various shell-forming animals. It is true that we find this same lime on the mud bottoms too, and it may even be mixed with the sand of the sand belt. The reader must understand that the different regions do not stop suddenly; they have no sharp boundaries, but if we walked, for example, from the mud region to the lime region, we would find that lime was making up more and more of the material of the ocean floor, and when at last so much as three-tenths of the material was all lime we would say that we had reached the lime belt.

And lastly we come to that region of utter darkness which is found in the most profound depths of the ocean. Here there is almost nothing but a dead, uninteresting, reddish layer which is called Red Clay. In these still and undisturbed regions it has been very slowly accumulating through many ages, having been very slowly formed from the gradual decay of fiery and volcanic rocks. It is here too that the dust of meteorites may be found. We have told in an earlier chapter how these bodies perform a wonderful journey through space, perhaps even visiting other sun systems beside our own. But at last one of them happens to strike our earth, and as it ploughs through our air it is burned up by the great friction. Slowly its particles fall downward through our atmosphere; they reach the surface of the ocean, and then still more slowly begin their descent through the water. Mile after mile, ever deeper and deeper, they sink, until at last they come to rest on the very bottom of the sea. Truly it seems to us that they have found but a dismal resting place after their wonderful journey through the depths of space.

HOW ROCKS ARE FORMED UNDER THE SEA.

We have now seen how great areas of the ocean bottom are covered with different materials; that is, we have learned how the waters ''sort out'' whatever they wear away from the land and afterward deposit it, some in one region and some in another. So far, we are taking a general, widespread view of the great processes of world building; there are many little corners of the ocean in which very different and very curious things are happening, and some of these we will tell about in a later chapter. For instance, in some countries land is being built up by the dust which the wind blows back from the shores of the sea; in many island regions land is added to by little coral insects, while in still other places the rivers are forming, first reefs, and then marshes, and finally solid land. But before we tell about these special ways of forming land, we must finish the story of how our great continents came to be, and of how the land of which the sea robs us is molded in a most wonderful way and at last given back to us as solid land again.

There are many most important questions which we must answer before we can fully understand the wonderful history of our world. How is it possible that all the materials that are spread loosely over the ocean floor may some day become solid rock? If we find how this happens, how can this rock ever be lifted up above the ocean to form new lands? Are we perfectly sure that our own rocks were once made in this way under the sea, and if we are, what is it that we find in them that makes us so sure? All of these most interesting things will be explained in the next few pages; and we will begin by telling how the rocks are really made under the sea.

All persons who live near a sandy shore, especially if this is near the mouth of some river, have seen long ridges of sea-shells which are formed at about the high-water line. Sometimes these ridges are many inches high and many hundreds of feet long, so that altogether there are hundreds of bushels of shells in them. Often several of the shells are stuck together, and in places where they have been undisturbed for some time one can pick up whole bunches of shells which have been cemented together in a large, irregular mass. Along the coast of Florida real shell-rock was once made in this way, which holds together so firmly and in such large pieces that it is cut into square blocks and used for building houses.

Such shell rock is made as follows: The water partly dissolves the lime which is in the shells, and this softened lime then becomes a regular cement which hardens and glues all the various shells together. And in the same way the very much smaller particles of lime in a lime layer may be cemented together and a firm, hard, limestone rock may be formed from them.

Sometimes the cementing material is made out of something quite different from the stones of which the rock is formed. For example, one of the best cements is that obtained when iron has rusted in water. When the iron parts of ships, or even little iron plates or bolts, sink to a sandy or pebbly bottom, its rust may in the course of only a few years bind all the sand and pebbles about it into one hard, compact mass. There is formed around the iron a regular hard rock, perhaps one or two feet through.

In nearly all parts of our country we find the kind of rocks called ''Pudding Stones,'' or Conglomerates. The merest glance will show us clearly that these are made out of many pebbles of different sizes which were worn round by the water and which afterward sank to some quiet place and became cemented together. The cement may be a substance called Silicon, which is a kind of mineral very common in the rocks of the earth and out of which common window glass is made, or it may be iron rust which got into the water from iron-bearing rocks that the early seas wore away, or it may be lime, or one of many other things. And so we see clearly that great masses of sand, or stones, or shells, may be cemented together into solid rock by the action of water upon them.

But there is another very important way in which solid rock may be formed, even when there is nothing in the water that could cement it together. This way is by pressure. As material is piled up ever deeper and deeper on the ocean floor, and as the mass gets heavier and heavier, its pressure upon its lower layers will become very great indeed. And at last under this great pressure all its lower part may become squeezed into one solid mass of rock. Men have actually made rocks in this way by squeezing loose materials very tightly together. We will soon learn that these layers are seldom left undisturbed, nor are they pressed principally by their own weight. After being formed into light rock they are often squeezed together sidewise with enormous force so that they are bent into great arches and wrinkles and folds. And wherever we find that the pressure has been greatest there the rock is made hardest and firmest.

All rocks made as we here describe are Layer Rocks; they are formed from the layers of material which the water has laid down. And although the rock layers may afterward become very much changed and distorted, we can always tell by studying them carefully that they are the layer rocks which have been made by the action of air and water. But it must not be forgotten that beside these there are Fiery and Volcanic rocks, which were not formed under the sea nor ever laid down in layers at all. The solid core of our earth and the backbones of many mountain ranges are made of fiery rock. These are part of the crust which first covered our cooling earth.

HOW WE KNOW THAT OUR LAND WAS ONCE UNDER THE SEA.

Probably many of our readers have seen or heard about places near their homes, which may be very far away from the sea, and yet in which great quantities of sea-shells are found. Perhaps they have at some time looked at some stones of which houses are built, and have found that these too were packed full of similar shells, or they may even have visited the quarry from which the stones came and noticed how its rock all lay in great layers and how the shells and other things were imbedded in these layers. The layers of stone look exactly like the layers of mud or sand which we see at the bottom of quiet water, and as if all these things had gradually sunk down to the bottom of the water and become stuck in the mud which is there. And this is exactly what the stone once was. Instead of being mud it may have been sand, and the things which fell upon it may have been covered with more sand, and at last the whole thick layer of sand with the shells inside of it was turned into stone.

We well remember many pleasant hours which we once spent hunting and digging in a sandstone quarry of this kind which is near Iowa City, in the State of Iowa. This is almost in the center of our country—almost as far from any ocean as it could possibly be—and yet the rocks are now packed full of the remains of numberless little sea animals. Strange as it may at first seem to us, it is not possible for us to doubt that these rocks were once the soft bed of an ocean; that it was at this time that the little animals were imprisoned there, and that long afterward the ocean bed was raised up and became solid land.

As we explained in the last few pages, such most interesting things can not be found in all rocks. In the first place, the rock of our quarry must be one of the new rocks; no animals or plants are ever found in the fiery rocks, for these became hard long before any living things existed on our earth. And in the next place, rock is often formed under such conditions that the remains of all living things have been ground to pieces before the rock became hard. And lastly, rocks are often so pressed and squeezed that all its interesting records are destroyed.

There are sometimes places where the record of what happened in the early ages is preserved in wonderful perfection. Among the very best of these are quiet bays which were protected from waves and all other disturbances, and hollows, or mud holes, which were slowly filled up by rising tides or by streams which flowed into them. In the stone from such places we can often find "Ripple Marks," made in the early mud by the wind-blown waves. And sometimes we even find little hollows made by rain drops; the falling rain made these marks in the mud, the streams swollen by the rain carried down new mud to cover them with a fine layer, and so preserve them, and at last when all has become solid rock the masons in splitting the layers apart come upon the record of this old, old rain-storm.

If the stone of our quarry was once the mud or sand of such a place as we have been describing, we often find a still more wonderful record of what was living upon our world so long ago. Some great three-toed bird, or some enormous reptile, may have walked across the mud, and today we look upon its monstrous footprints, indestructibly preserved in the stone. There is but one thing more interesting than this, and that is to find parts of the great creatures themselves which became imbedded in the mud and then were built up in the solid rock. As we will see later this has many times been done and we know with entire certainty that living on our land and swimming in our early seas there were strange and wonderful animals, very much larger and strangely different from any creatures that live on our world today.

Preserved in our rocks are the traces of the old seashores, of the wave-washed sands and pebbles, and even of the plants and animals which once lived in the sea. And from even a little study of them we would learn that many of the rocks and hills of our world were once deep below the waters of the ocean. But men can find out much more than this. They can often tell how deeply under the water a rock was, and in what kind of a place it was formed, whether near the mouth of a great river or in a sheltered bay or below a steep and rocky coast. And when in some new rocks they often find no interesting records, they can tell just what happened to destroy them. Beside this, they can tell which of the layer rocks were formed first, and which next, and so on, until we come to the newest of all. And so we know what parts of our country first rose above the sea, and how there were many parts which sank below the water again, and so changed from land country to sea country many times.

HOW OUR LANDS OF TODAY ARE RISING AND FALLING.

Can we see that parts of our land are even today rising farther out of the ocean, and that other parts are sinking below it? If the rocks tell us so clearly that during all the past ages these wonderful changes were always going on, we may surely expect that we may also find them happening now. Our world is not a finished world; the forces which have slowly brought it into the form we know will slowly change it into a different world during the ages of the future. It is ever growing and changing, but its growth is very slow.

And so we find that in very many places the seashore is slowly changing its position, and yet this change goes on so slowly that it is only by the most careful measurements that we can show whether the land is really rising out of the water or whether it is sinking below it. And yet it is probable that there is not any of our solid land which is exactly at rest. If we could measure very exactly how high it is above the sea, we would probably find that every different part is either rising or falling.

But sometimes the change is so clearly shown that everyone can see it without making any measures at all. For example, many years ago a temple was built near Naples, in Italy. The land afterward sank so far under the water that certain sea animals bored into the marble columns of the temple to a height of ten feet above their bases. And since then it has been lifted altogether out of the water again, although now it is slowly sinking. On rocks and cliffs which are along the seashore, but which are now high above the water, we may often clearly see where they have been worn away by the waves, and so we are certain that not very long ago they were much lower down than they are now, where the waves could reach them. We therefore know that the land along such coasts is now rising. In the early days of our country, sea-going ships could sail up the Potomac River to the little town of Dumfries, but the land has since so risen that the town is entirely above the level of the tide. And lastly it may be mentioned that the coast of New Jersey is sinking; we may see that the old meadows and forest trees are many of them already under the ocean. From careful measures it has been found that in this part of the United States it requires one hundred years for the land to sink two feet. It is no wonder that we do not easily notice such slow motions as this, and yet we can clearly understand that when they have continued for thousands of years they may entirely inter-change the places of the lands and waters of our earth.

In the very early days only the tops of the eastern and western ranges of mountains rose above the oceans, and it is probable that there was nothing to be seen of the United States then but these two broken chains of islands. At last a continuous range was formed in the east, and still later a similar long line of land appeared above the sea in the west, but for a very long time afterward the central part was covered by a great sea which stretched from where the Gulf of Mexico now is to the Arctic Ocean. The eastern mountains are far more rounded and worn away than those along the Pacific coast because they are so much older.

The great lowland between the mountain ranges at first extended only so far as southern Illinois. But the rivers slowly filled up the sea, and it was only necessary for this to rise a very little to form nearly all the solid land which now extends from this point to the gulf. In a later chapter we will see, however, that many parts of America have risen above the ocean and then sunk below it many times.

One reason why the northern shores of North America are so very rough and why there are so many islands both here and all the way along our coast from Labrador to Massachusetts is because these lands have recently been sinking. And both here and still farther south we find many excellent harbors for ships, because these deep harbors are nothing more than valleys which were worn in the land by rivers and glaciers before it sank beneath the sea. The old channel worn on the land by the Hudson River may be followed along the continental shelf from New York Bay for one hundred and twenty-five miles out under the ocean. And as we know that there is nothing else which could possibly have made this great groove on the land under the sea, we are sure that this part of the ocean bottom was once dry land across which the river was flowing.

WHY LANDS RISE AND FALL.

From what has been said we learn that we can not possibly doubt how our lands which seem so fixed and solid are not really fixed at all; how even the "everlasting hills" are by no means everlasting, but how they have been formed of great thick layers of rock which were once, ages ago, buried under the sea. And we have seen how careful observations show that our lands and mountains of today are no more finished than those of past ages were, but how on the contrary all the shores along our great continents are even now all of them in motion, some of them rising and some of them sinking under the water. It is true that these motions are all of them very slow. In the long course of centuries the change may be measured only in feet, or even only in inches, but it is these slow changes continued through thousands upon thousands of years that gradually but surely change the whole face of our world.

It is only because these never ceasing changes are taking place so very slowly that it is at first very hard for us to feel that they are taking place at all. But the more carefully we study the lands and rocks from all parts of the world,the more unmistakably do they tell us that all that we have been describing is surely true. From wherever they come they bring us thousands of evidences of their slow formation under the sea, and of how they were lifted up later to form the solid land. And as soon as we have been made certain that this must have been their wonderful history, a most important and interesting question is brought before us. This is the question why lands sink, and why they are lifted up. What wonderful forces are there at work to produce these wonderful changes?

Though many men have devoted years to the study of this most interesting question, we are not yet at all certain of the answer to it. It may seem to the reader a discouraging thing that of this problem, which is in one view the most important of all problems connected with world growth, we have as yet found no certain solution, but he will find that the more deeply he studies the natural sciences, the more interesting inquiries he will meet with which are awaiting an answer. Whatever part of the great universe he may select for his own life study, his experience will be the same. He will first learn more and more of what other students have found out, and the more he learns the more he will be impressed with the wonderful harmony which governs it all, and the more fully he will realize the deep pleasure which the study of nature ever brings. But in time he will come to the borderland of our knowledge. From here there extends an unknown country; to push on into this, to explore its deeper regions, hidden until now from the sight of men, and to add new discoveries to our already wonderful store of knowledge is perhaps the most absorbing and soul-satisfying occupation possible for the mind of man. For the more deeply we study the wonderful universe around us, the farther we must be led in our most imperfect comprehension of its Designer.

For many years men thought that the whole interior of the earth was melted and that all its solid surface was only a thin crust or shell around the great inner ball of hot and flowing matter. They thought we lived much as if we were on the thin shell of a great boiler—that by far the greater part of the earth was a hot, molten ball. And they thought that when a very great deal of weight was added to one part of this shell it would sink there, only to be pressed out somewhere else. And in this way they explained the rising of land in some places and its falling in others.

But we have now learned that the earth is certainly not at all like this. We know that it is rigid and solid to the very center; a great mass of solid rock, only the outer surface of which has been broken up into a very thin layer of earth or soil, and that this great ball yields less under a great weight than if it were a ball of solid steel. Yet even though the earth is so very solid, some men still believe that the elevation of the lands in some parts is caused by a sinking in others, as we have just explained. They say, as is well known, that even the most solid rocks may be squeezed out of shape, or will *flow* under a great pressure; that when millions of tons of earth are piled up in one place, as for example at the mouth of the Mississippi River, this part of the earth will surely sink under the great weight, while the parts from which the material has been washed away will rise. But the latest and most careful studies make it very improbable that the surface of the earth rises and falls much from this cause; the whole ball is so rigid that its shape can only be changed a very little by the washing away or piling up of the material upon its surface.

Very many men believe that the changes of level which we see on our earth are made by its slow cooling and shrinking. We have seen how the deep layer of air around our world protects us as with a blanket; how it holds the heat of the sun, and how we are kept warm exactly as if we were in a hot-bed. As long as this deep ocean of air is above us and the sun continues to pour its heat down through it upon us, it is not probable that the *surface* of our world will grow much warmer or much cooler. But we will learn in a later chapter that the inside of our world is very hot indeed. It is so hot that the rock which is there would certainly all be melted were it not for the wonderfully great pressure caused by the weight of all the rock above it. And this very hot inner ball must certainly be slowly losing its heat. We have learned that our world is surrounded by a cold of nearly 460 degrees below zero; although the air can keep us quite warm even in this intense cold, it can by no means so protect the inner core of the earth as to keep it indefinitely at its enormous heat of many thousands of degrees above zero. And so the inner core must surely be slowly cooling. And as it grows cooler it will certainly shrink together, and so become smaller than it was before.

It is believed that the uniform stone center contracts quite evenly. But as it shrinks away from the complex layer or "crust" made up of all kinds of materials, this must follow the shrinking center, and in so doing must become wrinkled and distorted, just as the skin of an apple becomes wrinkled when the inside of the apple shrinks away from it. It must be remembered that all the great mountains and lands of our earth form a very small layer indeed compared with the great ball below them. If we could stand off and look at our world with all its mountains and lands, it would seem to us even smoother than the round, smooth balls of a bowling alley.

It may be that the slow shrinking of the earth is the principal cause of the elevation of mountains and lands upon its surface. It may be too that the inconceivably great weight of material which is constantly added to the bottoms of the seas heats and weakens the rock below it and has much to do with fixing the places in which the rising or falling shall take place. And yet we are not sure whether either of these or whether both together are the real cause of the rising of the land or not.

It is remarkable that all the great mountain ranges of the world follow the shores of the seas, and neither of the two causes which we have just discussed show why this should be. But another most interesting theory has been quite recently developed, which seems to explain this occurrence of the mountains. This theory assumes that the waters of the oceans work their way down through the ocean floors until they reach a depth where the heat is so great that they are at once changed into steam. This steam pushes its way out from under the beds of the oceans and by its explosive force raises great land ridges along their shores. All of this theory will be fully explained in a later chapter.

HOW LAYER ROCKS ARE SQUEEZED AND BENT.

Sometimes after great areas of layer rock were formed under the ocean they were lifted up so evenly that we may now find them covering the land in almost level beds. The wonderfully interesting beds of rock through which the Grand Canyon of the Colorado passes are almost perfectly level layers which were formed in this way. But it is far more usual for the layers to become tilted and displaced as they are lifted up, and often at places where wrinkles and folds have been formed, they are bent and distorted in the most remarkable way. In such places it is often clear that the folds of rock have been formed by a tremendous sidewise pressure—a squeezing together of the layers with such an enormous force that they have actually been pushed up into arches and folds of solid stone. And not only is the rock often so pressed together that it is very much denser and heavier than it otherwise would have been, and not only are the shells and other remains of life in it completely destroyed, but even the hardest crystals which it contains may have been pressed flat by the enormous squeezing.

This folding and tilting of the rocks often makes it possible for us to study different layers, without having to dig below the surface of the ground at all. Layer after layer may have been added until the whole rock mass became many thousands of feet deep: if it had been lifted up evenly, we could never reach the lower layers until we had dug all the way through the layers which were above them. But if the layers have been tilted as they were lifted, and if the soil above them has been washed away, we may simply walk along the ground and come to one layer after another whose edges come to the surface. If we start at the top layer we may in this way study the rocks formed at all different depths just as well as if we could have dug layer after layer away to a depth perhaps of many miles. This tilting and folding of the rocks often brings layers of coal and other valuable minerals from great depths to the surface of the ground, where they may readily be obtained.

We will see that in successive ages of the world, different kinds of layer rocks were laid down. Some belong to the very young days of the earth, and in these we find the earliest beginnings of life. As the ages went by, new layers were laid down and in these ever higher and higher forms of life begin to appear. And so we can not only study the rocks of a given country and tell at what age of the world this country was formed under the sea, but by carefully studying the rocks of many countries we can learn quite exactly what the past history of our world has been. We will soon begin this most interesting story. But before we tell this history of our world, we must describe a few important changes which have been brought about by other things beside the wonderful action of the sea.

CHAPTER XXV.

Strange Things Which Were Made on the Earth.

HOW MOUNTAINS OF SAND MARCH INLAND FROM THE SEA.

IN the last two chapters it was several times said that land may be built up by the winds which blow from the sea. Indeed, many great lands are almost entirely wind-built lands, and we will now explain more fully the interesting way in which they have been made. We will tell how in some places great hills are formed, from three hundred to six hundred feet high, and how each hill is nothing but a pile of fine sand or dust which has been drifted by the wind, just as dry snow is often drifted in winter. Little by little such hills may build up a land high above the level of the sea, but an even more interesting way of land building than this is that which is brought about by a single long ridge of sand heaped up along the seashore. For such a ridge, or sand-hill, will sometimes march continually and steadily away from the shore, burying forests and towns and everything else which may happen to be in its way. It is a real, moving mountain of sand.

If the reader has ever visited a rather flat country lying along the sea, he has probably noticed a long range of quite high hills which extend in the same direction as the seashore but which are quite a long way from it. Perhaps these hills were so covered with trees and other plants that he did not notice whether they were formed of rock or not, but if he happened to see where a deep hole had been dug in them, or if perhaps a railroad was cut through them at any point, he may have found that they were nothing but great mounds of sand and dust all the way to their very bases. As we walk from these hills toward the seashore, we may cross many other ridges, but these grow smaller and smaller as we go on, and fewer plants are found on them, until very near the shore we find the last ridge of all, which is probably no higher than a man and is formed of such loose, dry sand that only a few patches of the toughest kinds of sedges and grass can grow on it.

These ridges are made of little particles of sand which have been blown away from the seashore. Twice each day the tide rises and covers hundreds of miles of beach with the finely ground rock called sand. Then follow several hours of low water; if the sun is shining brightly, the top of the surface of the sand becomes dry, and if a wind is blowing from the sea much of the dry sand is drifted inland so far that the waves can not reach it again. It may be drifted on until it is stopped by a patch of the tough beach grasses, and then it may begin to form a mound which buries them deeply. But this does not kill them, for in a few days they grow so long that they may be seen pushing out of the top of the mound and holding the whole sand mass together with their very long stems and roots.

Many such mounds are always seen along a sandy shore; they show us where the moving sand has been stopped by grasses or other plants, or possibly by some piece of wreckage or other thing. But more interesting than these is the long sand ridge, which is simply a drift, made as snow drifts are made in winter. If the strongest winds come from the ocean, the particles of sand on the ocean side of the drift will be continually blown over its crest and dropped on the land side. And in time they will become piled so deeply on the sheltered side of the ridge that a new crest will be raised farther from the shore than the old one was. And so the ridge will keep moving farther and farther inland.

As long as it is not too far from the shore, the sand ridge will keep growing larger, because it will be continually added to by the sand which drifts upon it from the sea. At last, when its journey has gone on for a long time, it will become so covered with plants that have gradually taken root upon it that its sands can drift but little. And it will have reached a point so far from the beach that only a little sand is added to it by the ocean winds; nearly all of this sand is now given to one or more other ridges which have in the meantime been forming between the old ridge and the ocean. And so when our sand mountain has come thus far its journey will be ended.

HOW A SAND HILL DID A STRANGE THING.

That a regular little mountain several hundred feet high can start at the seashore and march steadily across the land is so curious a fact we could hardly believe it if we had not seen just why so strange a thing takes place. That the winds should move a mountain seems almost an impossible thing, and yet we have seen that whenever the strongest winds are those which blow away from the seashore the sand must be ever moving inland. Along our Atlantic coast the principal winds blow away from the land and so this interesting inland movement is not so striking as it is in many parts of the world. And yet many sand ridges are to be seen here, because when a strong sea wind does come a great deal of sand is blown so far inland that it is caught and held by plants and so kept from afterward being blown out to sea again. And so the inland sand hills are found even here. On the other hand, the westward winds have in some places made the ridges move out into the water. The ‘‘Banks’’ of North Carolina which lie at a distance of twenty miles or more from the shore were made in this way.

When these hills begin their steady inland march they often do much damage, for they may bury thousands of acres of fertile farming country deeply under the dry and useless sand. Along the western shore of France the hills attain a great height and move to a very great distance from the ocean. This is because the winds which here blow away from the ocean are very much stronger than those which blow toward it. Even in our own country the sands have covered many fertile fields in this way and men have devoted much study to finding out how to stop their apparently resistless motion.

When we see that the sands are marching toward a country and that it is in danger of being buried, there is only one way in which we can save it. But fortunately this is a very simple way. It is only necessary to plant all over the ridge those tough sedges and grasses which can grow even in the dry sand, and they will bind the mound together and prevent it from moving farther. In the United States much money is spent every year for the protection of certain lands in this way. And in some countries the people plant pine trees between their fields and the sea, so that, years later, when the sand reaches these trees it will be held there until it becomes overgrown with grass and other plants and so becomes incapable of moving any farther. In desert regions of the earth where no plants will grow, great mounds of sand are often moved for long distances, and they may at last come to rest over an oasis or fertile valley and destroy all life there. There is no way at present known of preventing this destructive work of the sands of the desert.

The moving sand hills sometimes do strange things. In some countries one ridge follows another so closely that the whole land is changed into nothing but a great series of billowy hills. Rivers may be filled up and forced to flow in new courses, many miles away. Hollows may be formed where low places did not exist before, and so new lakes of water may accumulate there, or large tracts of country which were once dry and fertile may be changed into marshes.

But the most striking action occurs when the steadily moving sand ridge meets with a town or village. Although it very seldom moves faster than twenty-five feet a year and may even move so little as two or three feet, yet if it has not been checked by the planting of vegetation its onward motion is irresistible. And whatever is in its path will be sure to become buried. The little town of Eccles, near Manchester, England, was buried in this way more than one hundred years ago. The houses, and even the spire of the church, were completely hidden by the sand; a century later the church spire again began to appear, and in time the buried town may become completely uncovered, after having been hidden for more than one hundred years.

HOW LITTLE ANIMALS BUILD UP GREAT CORAL REEFS.

Probably every reader has seen at least one piece of the strange, hard substance called coral. It may have been a round, ball-like mass, or it may have been made up of twig-like branches, or it may have been one of the wonderfully delicate and fragile Fan Corals, so common in the islands southeast of the United States. For there are very many different kinds of coral, just as there are many different kinds of plants on the land, and they are of the most different and beautiful colors, although white, orange, and rose-colored corals are the ones most frequently seen.

The hard masses of coral are built up by little animals that live in the sea. When first born each one of these can swim freely, and it wriggles about, here and there in the water, until it finds a hard, firm place to which it can attach itself. From this time on, its journeyings are over. It grows into a sac-shaped creature called a Polyp, with a mouth opened widely to the water which flows over it, and from which it absorbs not only its food but also the lime from which the hard, coral masses are built.

Like many other, very simple animals, the little polyp increases in numbers in a very curious way. A little cell, or ''Bud,'' grows out from it, and this soon changes into just the same kind of polyp as its parent was. From this again there grow new polyps, and so on, until at last the single original one has spread or multiplied into a very great number. The whole colony of thousands of polyps are connected together by a common growth, and it is in this that the hard lime structure is formed. Generally, if one carefully examines a mass of hard coral he will find a very great many little hollows in it, each one of which was once filled with a living polyp.

Just as we saw in the last chapter how there are many very little sea animals which absorb the lime of the sea water to make their shells, so we now see that the little polyps absorb this lime in the same way and form hard coral masses of it. But the coral animals by no means cover the deep bottoms of the oceans with lime as the other little animals which we described are doing. For their whole life history is very different. In the first place, they are fastened to some firm object and are not carried back and forth by ocean currents. And beside this they can only live in very special places. No corals can live above the water, and very few of them can live more than one hundred and twenty feet below its surface. The water in which they grow must be very warm; it must be free from mud, and must have enough of a current to continually carry past them the food on which they live.

We therefore see that coral can only be formed in the clear, shallow, warm waters of the tropical seas. As it can only grow in shallow water, we find that in such places there are great patches, or ''Reefs,'' of coral, which are either attached directly to the land or else are formed in shallow water farther out from the shore. The first kinds of reefs are called Fringing Reefs, and the second kind, Barrier Reefs. A great barrier reef runs along nearly the whole north shore of Cuba, while a little way off from the northeastern coast of Australia there is the largest coral structure in the world. This is a great strip twelve hundred miles long and from ten to ninety miles wide. It is from twenty to eighty miles distant from the shore, and inside of the reef the water is so deep that coral can not be formed there.

These wonderful coral reefs are indeed a beautiful and interesting sight. The Bermuda Islands, lying eastward from Virginia, and all of the waters from Florida throughout the West Indies are coral regions; possibly some of our readers have had the good fortune to see for themselves these wonderful formations in some of these places. An eminent geologist, the late Professor Angelo Heilprin, thus describes his first view of a coral reef, which he visited at a point about nine miles north of the Bermuda Islands:

"Looking over to the ocean side, one sees a wonderful assemblage of living animal forms, the greater number of which are clumps and heads of various kinds of coral, some small, others measuring several feet across. Luxuriating near the surface of the water, and in their various colors and shades of orange, brown, and purple, they are spread out before the eye like the pattern of a mosaic pavement. Well in among these coral masses are a multitude of sponges,—black, yellow, and vermilion,—various coralloids, sea-fans, and squirts, all of them firmly attached like the corals themselves, while between them run about an army of crabs, of colors hardly less brilliant than those of their immediate surroundings. A variety of shells is invariably associated with the growing reef, and in the numerous holes and crevices the eye can not fail to detect the spines or hard cases of a number of sea-urchins. This is a picture of a coral reef, but one which carries with it no conception of the rapturous beauty of its construction. No flower-garden of the earth surpasses it in wealth of kaleidoscopic coloring:

and it may justly be doubted if any approaches it, for the silvery texture of the over-lying water adds a luminosity and brilliancy to the scene for which neither the calm atmosphere nor the warm sunshine can offer a substitute. To have seen the world without having visited a coral reef is to have seen a picture with the best of its coloring left out.''

WHAT WE MAY LEARN FROM CORAL REEFS.

From a careful study of the coral reefs we may find many beautiful illustrations of the very important processes which we have already told about as having had much to do with changing the form of our lands. For example, all the rocks and lands of the Bermuda Islands are formed of limestone, but the source of all of them has been the near-by reefs of coral. The sea has ceaselessly broken off great pieces of these reefs; it has cast them ashore and ground them to powder and the winds have gradually blown this powder over the land and so built up the islands higher and higher. And finally, very many of the mounds of lime have become cemented into a solid rock, exactly as was explained in the preceding chapter.

The Bermuda Islands have therefore been built up by the wind. In other places the surfaces of the reefs are broken and ground into fragments of all sizes, from great blocks of coral to the finest mud; all of this, together with sea-shells and much other material, may then be swept by the currents into quieter waters, and then the whole will become firmly cemented together. A layer of such material three inches in thickness has been seen to form after a single violent storm off the Florida coast. Much of the layer rock of past ages has been formed in this way, for it is known that coral and similar animals appeared on our world in very early times. And some of this rock is even found within what are now the Arctic regions. This alone tells us clearly that in those early days the water of these polar zones must have been as warm as that of our tropical zones is today.

In many regions we find masses of coral which rise up from a depth of many hundreds of feet below the surface of the water. But we have seen that the little coral animals can not live in water so deep as this; we can therefore be quite sure that when they first began to build, the water was much more shallow than it is now, that is, that the floor of the ocean has been sinking in these regions. And in other regions where coral structures are now found rising many hundreds of feet above the sea we can be sure that the land has been lifted up.

So we see that from a study of the coral rocks alone we might have learned how land is formed by the wind, how limestone rock is sometimes made, how the climate of our world was once very different from what it is now, and lastly, of how the beds of the sea are rising in some places and falling in others.

One of the most interesting kinds of coral formations are to be seen in great numbers in certain parts of the Pacific Ocean. These are simply little narrow ridges of coral rock which rise above the sea and enclose a body of quiet water within them. It is believed that each little coral ring was in earlier times a fringing reef about a small island that was slowly sinking. As the land sank lower the reef was built higher, until now that the island has entirely disappeared below the water, there is nothing but the round, bordering coral rim to be seen. Powdered limestone and other fine soil material has been added to the surface of the rim, just as it may be on other coral reefs, and the seeds of many plants, and especially of the palm tree, may be washed upon it by the waves or blown there by the winds, so that in time the narrow rim becomes covered with an interesting tropical vegetation. But these coral islands are not large enough or high enough above the sea to afford pleasant homes for men. But few animals are found upon them, and their shores are raised so little above the water that during heavy storms the largest waves often wash completely over them.

BLACK BOGS IN WHICH COAL IS MADE.

Everyone knows how falling leaves may accumulate for year after year on the ground, and how as they gradually decay they become partly changed into a kind of rich, black soil. If we walk through any forest whose trees have been growing on the same land for many generations we will always find that there is a layer of this black soil beneath them, even although all the land around the forest is made of sand or yellow clay, and is not black or rich at all.

The black earth of the forest is what is left of the leaves and branches which have been falling from the trees for year after year, but unless the forest is a very old one indeed we would find that there was only a very thin layer of black soil in it; if we should dig down through this for only a few inches, we would come to the sandy or clayey soil which lies beneath it. The layer is so very thin because it requires very many leaves indeed to make even a very little soil; if so many leaves and branches were spread over the ground that they covered it everywhere deeper than your head, yet as the years went on the thick bed would settle more and more and at last form a layer of black soil much less than one inch deep.

This is because as the leaves decay nearly all of the materials of which they are made are slowly changed into different kinds of gases which escape into our air and are carried or blown away. In an earlier chapter of this book, when we were telling about the strange little world called Mars, we explained how the plants all absorb from our air the gas called Carbon Dioxide, and how from this they obtain the pure, hard carbon out of which they are largely made. Now when the plants die and decay in the air, they turn back almost entirely into this poisonous gas again; only a little part of their material is left to become a solid earth.

But when leaves or branches or any other parts of plants fall into still water, a very different thing happens. Then they partly decay, and they partly change into gases which rise to the surface of the water and are blown away by the air, but very much of their material remains in an almost solid condition. They begin slowly to change into almost pure carbon, and so little by little the bottom of the water becomes covered with a thick, black mud. This will happen whenever trees or other plants have been growing for centuries in standing water, or in very wet, stagnant marshes. The whole wet mass is called a Bog, and the partly decayed material which fills it is called Peat, so that such vegetable accumulations are called Peat Bogs.

Peat bogs are often formed because the soil is of clay or other hard material through which the water from rains or streams can not drain away. If there is a hollow place in such a soil, it will hold water just as a pan or dish would do, and the plants growing about it will in time change it from a pond or lake into a peat bog. Often these bogs are very large and very deep. Plants of all kinds may cover their surface so thickly that they bind it together into a kind of crust, across which men and animals may walk in some places. But this is a very dangerous thing to do, for everywhere below the crust there is nothing but a deep, tremulous mire of thick, black mud, into which if one should sink nothing could possibly save him.

Nearly one tenth of the whole surface of Ireland is covered with peat bogs, and there are very large ones in England, France, the northern part of North America, and many other places. Those which are far north have been principally made by a kind of northern moss called Bog Moss, but other bogs are formed by trees and water plants, and in fact by a mixture of plants of all kinds. As all of this material is excellent to burn when the water has been dried or pressed out of it, many peat bogs are of great value on account of the fuel which may be obtained from them. By pressing the peat very powerfully together, it may be formed into blocks which look almost exactly like coal and which burn nearly as well.

And this brings us to one of the most interesting things about these strange, black bogs. For they are places where coal is even now being made. If we could dig down to the bottom of a very deep and old bog, we would find that the deeper we went down the more nearly like coal the peat would become. On the surface and near it there would be only a loosely compacted mass of twigs and branches and plants, but below this it would become denser and finer until when we reached the very bottom, where the peat has lain for centuries under the weight of the mass above it, we would find a material so black and compressed that it had become almost a perfect coal.

The great coal beds of the earth were formed in almost this same way. But the plants which grew in the early ages and made these beds were very different from those which are on our earth today, and we will see later that the great marshes and bogs in which they lived were often sunk below the sea and afterward raised above it again. Much of the soft coal was made by simply lying in these bogs for a very long time, but sometimes during the great changes which our world has undergone some of the beds of soft coal were heated and squeezed together by enormous pressures and then became changed into hard coal, or Anthracite. And a few kinds of coal had a still different history. The light, brownish coal known as Cannel coal, which is so useful for the gas of our houses, was formed in ponds of clear water and not in bogs. Fishes which swam in the waters of this early time are sometimes found in this kind of coal.

SOME STRANGE THINGS WHICH HAVE BEEN DUG OUT OF PEAT BOGS.

Suppose that some unfortunate animal should come to the margin of a peat bog and start to walk across it. For some little distance the treacherous crust might bear him up in safety, but before long he would be very apt to break through, and then he would begin to sink slowly down through the black mud which lies below. The poor animal would be at once drowned in the mud, but his body would sink deeper and deeper and at last come to rest very near the bottom, and there it would be preserved for many ages. This must very often happen. Many peat bogs are very like the traps which savages build by digging a deep pit and covering it with an insecure layer of branches and leaves. Animals are continually walking out onto them, attracted by the bunches of grass or other plants which grow there, only to break through and end their lives in that deceptive spot.

And there the bodies of these animals remain. It may be that the people who shall be living on our earth many thousands of years from now will dig away many of our peat bogs and be much surprised by the strange creatures which they find buried there. For we ourselves have found a wonderful number of animals in just such places which have been preserved for many ages. In the bogs of Ireland there is sometimes found the magnificent Irish Elk, a great, deer-like creature, sometimes no less than twelve feet tall and whose antlers measure as much as twelve feet from tip to tip. The enormous Big Clawed Sloth and great Mastodons and elephants are found in the bogs of our own country. From one single place in Kentucky it is said that the remains of no less than one hundred mastodons and twenty elephants were dug up. In a marsh near Newburg, New York, a great mastodon was found with its head thrown up and its legs bent under its body in just the position in which it was caught in the mire. In its mouth there were still the remains of the twigs of evergreen and other trees of which it had been eating.

It will be noticed that the animals found in these places are nearly all land animals, and that they are principally plant eating, or "herbivorous," animals, for it is these who would be most likely to be tempted onto the crust of the bogs. We will learn later that there are very few ways in which the bodies of the early land animals can be preserved to us. Innumerable creatures in the sea may sink to the bottom and at last become encased in the rock which is forming there, but the bodies of the animals which live on the land will almost always be destroyed. And so we know much more of the strange creatures which lived in the very early seas than we do about those which lived on the land. The study of what the peat bogs and the softer coal beds have to tell us is therefore of great interest and importance.

Sometimes when searching for traces of such early creatures men make a far more sad and striking discovery. One hundred and sixty years ago, there was found in a bog in England the body of a woman who had sandals on her feet. And deep in an Irish bog the body of a man was once found which was clothed in coarse hair-cloth. How many, many centuries have passed since the day when each of these people was drawn down into the treacherous marsh! Doubtless they lived before the English nation first began: little did they dream of the wonderful means of civilization and happiness which were to come to mankind before their bodies should be released from their dreadful prison.

CHAPTER XXVI.

The History of Our World.

HOW WE READ THE HISTORY OF OUR WORLD.

WE are now ready to tell the wonderful story of the life of our world—of the strange things that have happened to it since that very early time when it first began to change from a great mass of hot and flowing matter to a hard and solid ball. We can probably never make the story entirely complete, for in many cases the record of what was going on during long periods has been destroyed, and so we shall find that in some places there are breaks in the story. Only a few years ago there were very many such breaks, and they were very large ones, but by patient study of the rocks from all over the world these unknown epochs have been reduced in length more and more, until now we can tell with great certainty almost every step of our world's development.

We have learned how the hard rocks of the land are washed into the sea; how here the finely divided material, often with the remains of animals and plants imbedded in it, is slowly formed into a new rock, and how this newly made rock is lifted up to become the solid land again. But the process does not stop here. It is repeated again and again as age after age goes by. If we dig deep down through our land, we may find layer after layer of different kinds of layer rock, of which the very lowest of all was formed first, the layer on top of that formed next, and so on, until we at last come to the highest layer, which is the newest of all. The time required for all these different kinds of rocks to be formed one after the other, is to be expressed in millions of years; and during all this long time the animals and plants of our world have been ever changing. They have ever developed from the simpler forms of life into those which are more and more complex and perfect. And so, if we should find traces of them in each of the layers of rock, the remains found in the lowest layers would be those of the most simple animals of all; in those which were laid down many ages later we would find traces of much more perfect, though strange and larger creatures, which have long ago perished, while in the highest layers of all we would find the creatures which lived just before man appeared on the earth.

We therefore see that if we could find in any one place the layers belonging to all the successive ages of the world, and if in each of these layers there was preserved a record of the life which existed while it was being laid down, then from a study of this single place we would learn the whole history of that part of our world. But if we think about it for a moment, we will see that we must not expect to find any one single record like this. In the first place, any part of our land may have been above the seas during any one age, or even during many ages, so that throughout all this time not only was there no new rock added to it but very much of the rock which had been formed there before was being worn away. Indeed, some parts of our world have been dry land almost from the very beginning; here we find no layer rocks at all, and from these places alone we could learn almost nothing about the past history of our world. Again we have seen that only a very few of the remains of animals and plants are preserved. Of the great host of living things on the world it is only the records of those in very specially favorable places that can come down to us. And lastly, we have seen how, even after they have been apparently imperishably sealed in the rocks, very many of these records may be destroyed. By heating, by pressure, and in many other ways, the rock may be so changed that it no longer tells us anything of the forms of life which covered the earth while it was being formed.

If we could only study the rocks from one part of our world our knowledge of what has taken place would therefore be very incomplete. But if the rocks belonging to one age are not to be found in one country, they must be sought for in another. And although the records of the various forms of life that existed in this age are not all found in any one place, yet by exploring the rocks of this time wherever they exist on the earth we gradually find more and more traces of living things, and at last are able to tell quite clearly just what animals and plants were most numerous then and what the conditions on the world at that time were.

From a very careful study of the rocks of many countries in this way, geologists have learned the whole general history of our world. This most fascinating work is being all the time even now carried on, and more details are being continually added to our already large store of knowledge. Every little while the remains of some new, strange animal or plant hitherto unknown are found, and our record is growing more complete every day. Yet a very large portion of the earth remains almost wholly unexplored. We can not doubt that for many years to come new facts will continue to be brought to light which will be no less interesting than the discoveries which have been made in the past.

THE SEVEN AGES OF THE WORLD.

From the very beginning our world changed its condition steadily and very gradually, just as it is ever changing even now, and as it slowly grew to be different, the various kinds of living things upon it all changed steadily and very slowly too. At a very early period of its history there were no animals upon it higher than the very low forms of sea life called Mollusks; later the waters of the earth became swarming with fishes, but as yet there were no reptiles or mammals on the world at all. A still later age was to come when great reptiles increased so wonderfully in numbers and became of so terrible a size that they for a time dominated the earth, and still later the few little mammals which had been found on the earth before were now so developed that they became the most important of the living creatures of our world.

From these things the geologists have found it convenient to divide the whole history of the world into seven great Ages, or Epochs, each named after the most striking thing to be found on the earth while the age lasted. The time which belonged to any age was so very long that these seven great divisions are not nearly enough if we wish to tell more exactly when any past event occurred, and so in larger books than this one a very many smaller divisions will be found. Nearly every age is divided into smaller times called Periods, and these are usually named after the principal rocks which were formed while the period lasted. It would be most interesting if we had the space to show how life gradually changed from each period to the next, and to tell where on the earth the rocks of each successive period are to be found. But if the reader wishes to learn the story of our world in such detail as this, he must look for it in very much larger books than this. The seven great ages of the world are as follows:

1. The Azoic, or Lifeless Age, in whose rocks no certain remains of life can be found.
2. The Age of Mollusks, or simple sea animals.
3. The Age of Fishes.
4. The Coal Age, when our great beds of coal were laid down.
5. The Age of Reptiles.
6. The Age of Mammals.
7. The Age of Man.

We will now describe the conditions on our earth during each one of these great ages.

THE AZOIC, OR LIFELESS AGE.

The earliest rocks of this age are those which were formed in the very beginning, when our earth had first cooled enough to form a solid crust. Others are those which were formed from the material that was worn away from this crust, or dissolved from it by the boiling hot waters of the early oceans, while the latest of all were formed in much this same way when the oceans had become somewhat cooler. It is therefore thought that these last were once true layer rocks, but they have been so wonderfully squeezed and changed that often not the slightest trace of their once layered structure now remains. By great heat and squeezing they have been changed into the heavy, dense rocks called Granite, Gneiss, Quartzite, etc.; in some places they have passed directly through great masses of rock which lay above them, showing clearly the enormous pressures accompanied by the great heat to which they have been subjected. Very many crystals are found in these rocks and most valuable beds of metallic ores; indeed, iron ore is here so frequent that a part of this time is sometimes called the Age of Iron.

The changed rocks of this time are found all over our entire earth and they form beds of enormous thickness. In some places these beds are no less than forty thousand feet thick, and they form the foundation upon which the rocks of later ages lie. The wearing and dissolving away of the land rocks by the early waters of the earth was doubtless much more rapid than it is now, since the waters were then hot, and even the air of the earth was probably very hot and filled with steam, but in spite of this we may be sure from the immense thickness of the rocks that the Azoic age lasted a very long time. It was probably longer than any other age of the world.

Although we call this the Lifeless Age, it is very probable that toward its close some very low forms of life began to appear. Many believe that the beds of crystallized limestone, as well as the occurrence of Graphite and iron ore show this, for we now know no way in which these things can be formed except by the action of plants or animals. Yet it is quite possible that they were formed in other ways in the Azoic Age. However this may be, if in this early time there was any form of life on the earth at all, the extraordinary changes which the rocks have undergone have destroyed all traces of it.

THE AGE OF MOLLUSKS.

The next great age of the world also lasted for a very long time indeed. The waters of the oceans had now become much cooler, the terrible disturbances to which the heated surface of our earth was subject had become much less violent, and the air, though doubtless still very wet and hot, was beginning to grow lighter and rarer. Already the main outlines of the principal continents had appeared, and from now on their growth was to be on the whole steady and constant.

All through this long age the lands were being pushed up higher and their surfaces worn away to form great beds of layer rocks under the sea, until at last these new rocks formed a total depth of nearly sixty thousand feet. We know that by far the greater part of this great mass was formed in comparatively shallow parts of the ocean, although many fresh water beds have also been discovered. In some places the layers have been lifted above the waters during later ages and also tilted up, and the upper surface of their edges has been worn away, so that by walking along the present surface of the ground we may pass across all the layers from the very oldest to the newest. If we walk in this way due south from a point in Canada, about two hundred miles north of the west end of

Lake Ontario, until we come into Pennsylvania we will see them all. When in Canada we are standing on the highly changed, dense rocks of the Azoic Age; as we walk southward we come first to the very earliest layer which lies upon these, then to the later and later layers one after another, until, about fifty miles south of Lake Ontario, we step onto the exposed edges of the lowest part of the layers which belong to the age of fishes, and soon after we have crossed into the State of Pennsylvania, we see around us the rocks that belong to the age of coal. Thus we can study and explore these different layers one after another, very conveniently, while if they had not been tilted edgewise as they are we could only find out about them by digging a hole down into the ground all the way from the newest to the oldest rocks; and to reach the very lowest layers the hole would have to be at least five miles deep.

In the very lowest rocks of this age we find the first certain traces of life on our world. As yet no plants have been found nor any land animals, but only the simplest forms of the life of the sea. Imbedded in these lowest rocks are the remains of sponges, jelly fish, star fishes, corals, and very many other simple animals, but most numerous of all are two kinds of creatures known as Brachiopods and Trilobites. The first of these have a two-valved shell, as oysters and clams do, and the second are strangely shaped animals having a three-lobed body and looking something at first glance like our present familiar "horse-shoe crabs." They were very large animals for this early time, sometimes reaching a length of two feet; they have two eyes which are compound eyes like those of the fly and many other insects. Because they have eyes, we know that even in this very early age there was light on our world. Not only the trilobites, but nearly all the animals of this early age totally disappeared from our earth long ago. They were the beginnings from which the higher forms of life slowly developed, and as the new forms were better fitted to live on our world, the simpler forms slowly grew less and less in numbers and finally entirely disappeared. The last living trilobites are to be found in the age of coal.

As we explore the newer rocks of the age of mollusks, we find, not only that the seas become more filled with swarming life, but the number of different kinds of living creatures enormously increases, and the forms of the newer kinds are more perfect and less simple than those of the earlier ones. At last, in the very upper layers, we find for the first time the remains of true land, or air breathing, animals. From now on, life will remain on the land as well as in the sea, but it is most striking and interesting to think of how the seas were the early cradle of life; how the beginnings of life from which all living things on our world were developed are to be found only in the ocean. The earliest land animals were only insects and scorpions; long ages were still to pass away before the very highly developed, warm blooded animals could begin to appear. And in the very latest of all the rocks of the age of mollusks we find the scales and spines of fishes, telling us clearly of a wonderful upward development of life forms, and leading us naturally to the next great age of the world.

THE AGE OF FISHES.

All through the rocks which were next laid down we find the remains of an extraordinary number of fishes. They were the rulers of the early seas; the simpler forms of life on which they preyed existed in such quantities and were so defenseless that there was nothing to prevent the almost indefinite increase of these new, higher animals. Indeed these early fishes could have had almost no enemies except as they were enemies to each other. And so we find that they increased wonderfully in numbers and in different kinds, and that many of the simpler animals on which they fed began to grow fewer.

The fish of this age would have looked to us much like the fish which we see on the earth today; they had tails and fins, many of them were covered with scales, and their shapes were very like the shapes of more recent fish. But there was one very great difference, and this was that they had no hard bones as our fish have. Instead of these their skeletons were formed of a very tough material called Cartilage. Many such soft-boned fish live on the earth even now, of which the skate, shark and sturgeon are examples, but by far the greater part of our fishes of today have a hard, bony skeleton.

Could we have visited the world in the age of fishes, we would have seen no large land animals, no four-footed or warm-blooded animals of any kind, no reptiles, and no birds. Everywhere there would be silence, for no animals which then lived had any kind of voices or were able to make any sounds. Yet even this world would be much more like the world we know than the world of the preceding ages. The lands are now covered with forests in which trees grow sometimes to a size as great as three feet through: ferns and mosses and other low plants are everywhere, but as yet we see no flowering plants of any kind. May-flies and other insects are in the forests, centipedes are in the dryer regions, and crabs are found along the seashore. We know too that during this age the earth had become so cool that there was a period of growth and one of rest in the temperate regions; that is, that there was a warmer and a cooler season each year just as there is summer and winter now. For when we cut through the trunks of the early trees we find a ringed structure, just as we do in the trees of today. One hundred and fifty rings have been counted on one trunk, showing that even in this early age a tree might continue to live and increase in size for more than a century.

THE AGE OF COAL.

There next followed a long, long time while the great forests of the world were slowly building deeper and deeper the layers of black, peaty material which were to become dense and hard and form our great beds of coal. We have already seen how coal is made, and how it is forming in many parts of our world even now. And we have seen how very long a time it takes to form even a very thin layer of coal. The thickness of dense coal in some beds is so great as one hundred and fifty feet, so that we are sure that these beds were hundreds of thousands of years, and probably more than a million years in forming. All of the time which has passed since our very first records of any civilization on the world is at most only six thousand years: even the great pyramids of Egypt were built less than five thousand years ago. We can hardly realize so long a time as this, while so enormous a time as one million years is altogether beyond our comprehension. Yet the coal age lasted a much shorter time than any of the ages which we have described so far. The changes brought about in the form and life of our world take place very slowly, but they have been continuing and will continue through periods of time whose vastness is utterly inconceivable.

Throughout the coal age, and before it, our world was a very flat world. It was covered with great wide seas, and what land there was rose but little above the water. On these low continents there were immense swamps, some of them covering hundreds of thousands of square miles, and the waters of these swamps extended to the seashores and merged into the waters of the ocean. The air was hot and still, filled with poisonous carbon dioxide, and so stifling that it could not have been breathed by warm-blooded animals. But it was just this kind of an atmosphere that was exactly suited to the growth of the dense forests, and so during all this age generation after generation of great trees and other plants lived and died and were preserved in the form of coal.

During the coal age, and especially toward its close, the low lands in many places rose and fell a great many times. These changes went on slowly and quietly, and the result of them is that there are many layers of coal alternating with shales and slates and other water-made rocks. The coal layer sank down, rock was formed on top of it, the whole was then raised and another layer of coal placed upon the rock, and so on, a very great many such layers being found in some coal beds. And sometimes the standing trunks of trees with all their roots have been preserved by the rock which formed around them; we may dig this rock away and see them standing, just as they grew so very long ago.

During this long age life continued to grow more varied and interesting. Beetles and spiders appeared, the trilobites vanished from the earth, and, most important of all, a great many animals of the kind known as Amphibians began to emerge from the sea. An amphibian is usually an animal which lives partly on the land and partly in the water. Some are without tails, of which frogs are the most common examples; others, like the salamander, have tails, while still others are strange, snake-like creatures. All, as they grow, go through a most wonderful change of form, just as the well-known frog first comes into the world as a fish-like tadpole, and afterward so changes that it can live on the land.

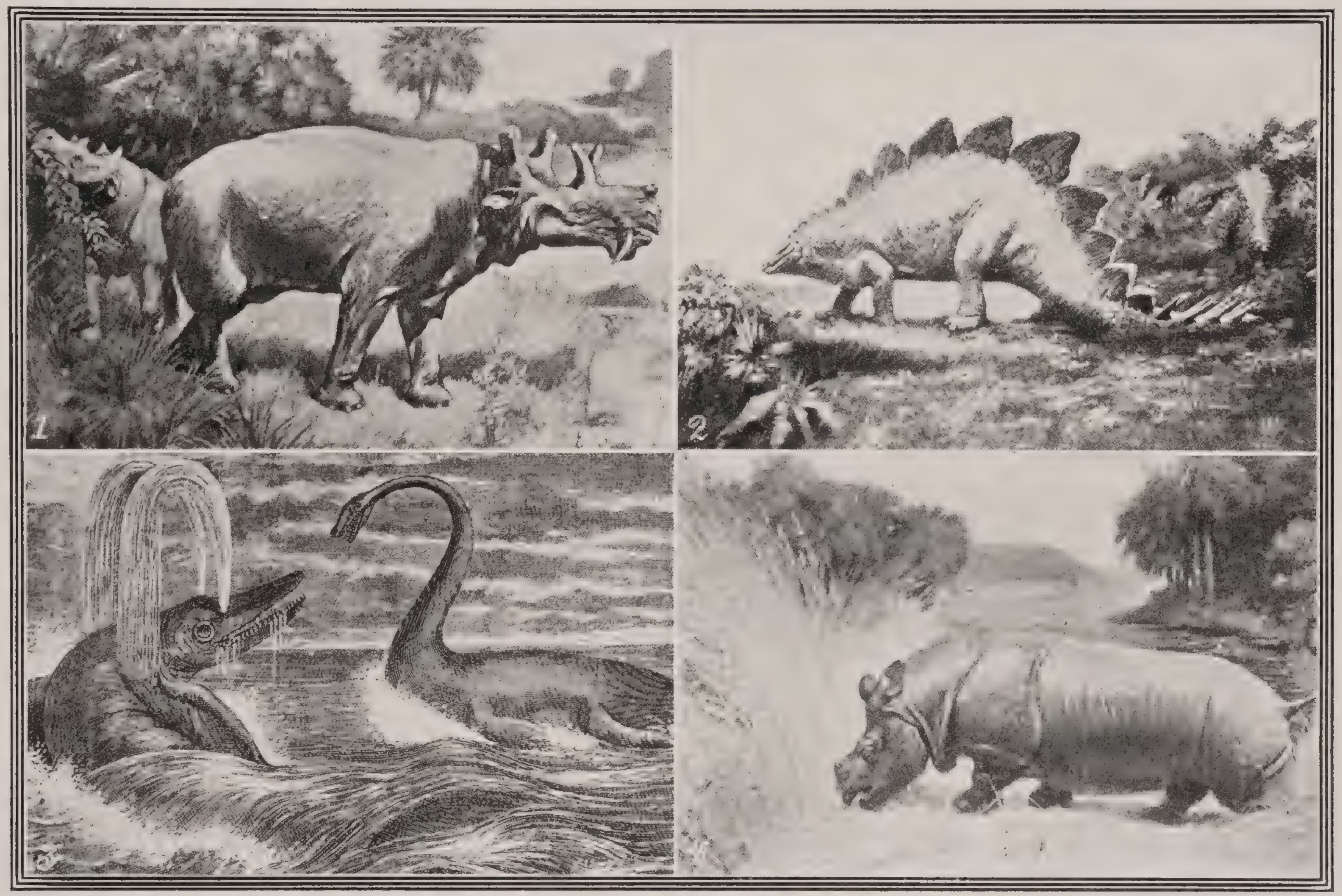
The amphibians of the coal age were many of them gigantic reptiles, with enormous, heavy bodies and weak legs, with which they dragged themselves slowly over the land or through the marshes. Their bones were not hard, but cartilaginous like the bones of the early fishes, and some of them had paddles instead of feet. In the flat stones of the coal measures the tracks of these great crawling reptiles are sometimes found, showing not only their great feet but also the marks made by their dragging tails.

Interesting as is the first appearance of these great reptiles on the land, it is only a faint forerunner of what is soon to appear. For this type of new creature, able to wander over the land or to swim in the water, and made terrible by its great teeth and enormous size, is soon to take possession of the whole world. It will develop into innumerable animals of most wonderful size and strength; for a whole long age no enemies can resist or overcome these new creatures, but at last they will give place to a new, as yet undreamed of form, which will itself be conquered by an even more perfect creature when the time appointed for the end of its dominion on the earth has come.

THE AGE OF REPTILES.

From the few reptiles which appeared during the preceding age there next came the most marvelous and extraordinary forms of life that have ever appeared on our world. These enormous and terrible reptiles not only swam in the sea and walked over the land, but some of them actually flew through the air, and these last were the strangest looking creatures imaginable, and not less terrible than strange. At this stage of our world's history the reptiles ruled the earth. Could they again appear in such numbers today, there is little doubt that they would quickly destroy and devour all the higher animals with which the earth is now filled, and even man would, for some time at least, be powerless before them.

In the seas there swam a multitude of enormous monsters. The Ichthyosaurus was no less than forty feet long: its great head was five feet long and armed with terrible jaws which had two hundred sharp teeth in them: its eyes were fifteen inches across. The Pleiosaurus was another monstrous reptile with a great, turtle-shaped body, a long, snake-like neck, and terrible jaws and teeth. It grew to be thirty feet or more in length. These and a vast number of other great crea-



1. A strange, long-headed, four-horned creature whose remains are found in Wyoming. 2. The great Plated Lizard or Stegosaurus, from the western United States. 3. The Ichthyosaurus (on the left) and the Plesiosaurus (on the right). 4. An early, short-legged Rhinoceros whose remains are found in Kansas.

tures doubtless lived on the fish of the sea and on such weaker reptiles as they could catch and devour. We can easily imagine that a reptile as large as a house and armed with such terrible jaws and teeth need fear none of the animals of the earth except other reptiles as powerful as itself.

On the land there were crocodiles and other large crawling reptiles, but besides these there were other wonderfully large creatures, some of them sixty or seventy feet long, which walked with a free step. Some of these ate the plants which then grew so abundantly, but others preyed on other animals, and they were terrible enemies indeed. Like the reptiles of the sea, they had enormous jaws armed with sharp teeth, but unlike these they had true feet instead of paddles, and their feet were armed with sharp, curved claws.

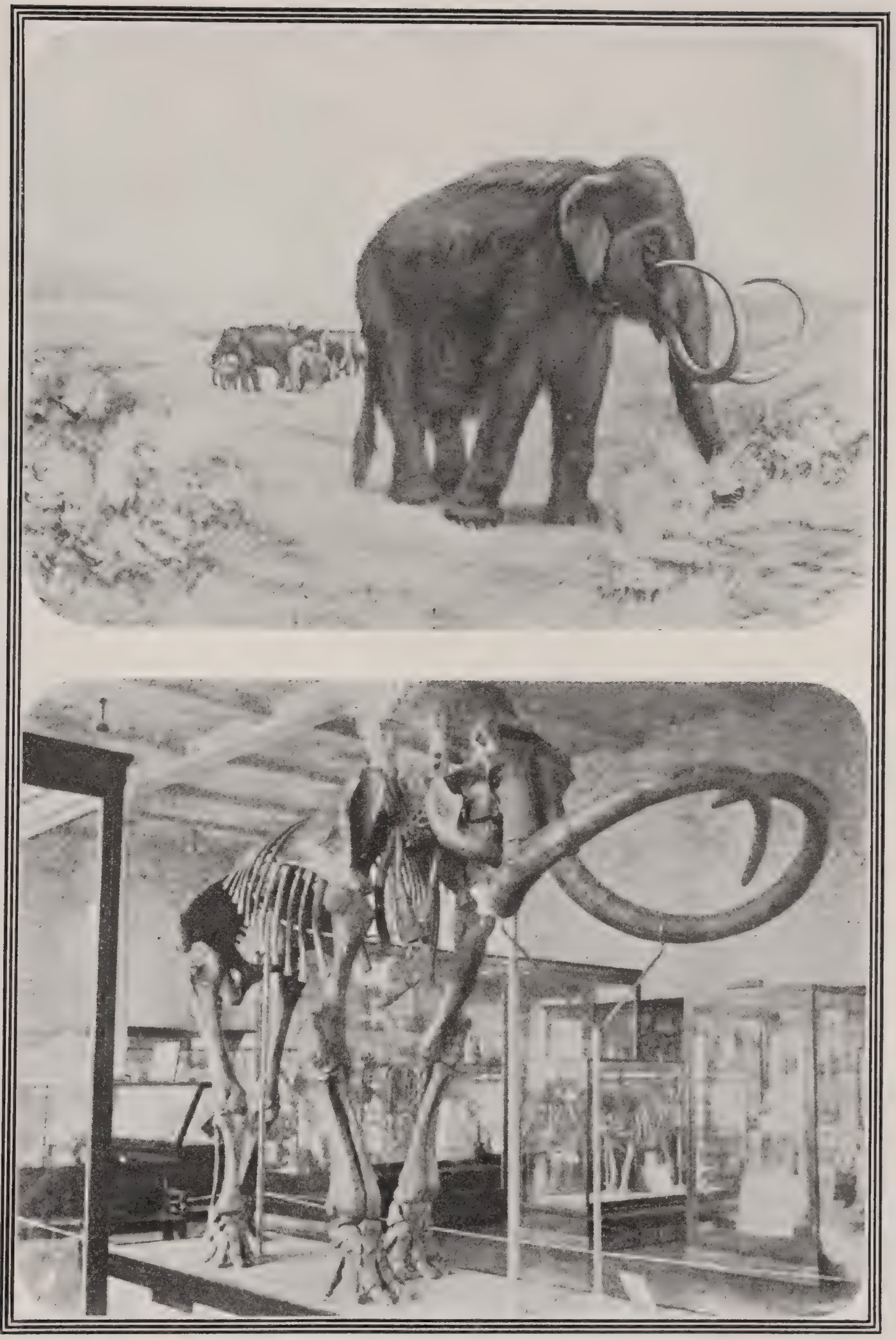
But most wonderful and striking of all were the great reptiles which flew in the air. The forms of these are so extraordinary that we could hardly believe that such creatures ever lived on our earth were it not that their skeletons and other remains which are sealed in the rocks tell us so clearly of them that we can not possibly doubt it. Some of them were like very large birds and had true feathers, but unlike any birds now living on the earth their mouths were provided with sharp teeth. Others bore more resemblence to bats, but such bats as, very fortunately, we no longer ever see. They were indeed veritable flying dragons, some of them so large that their outstretched wings extended no less than twenty feet.

The feathered reptiles seem to have been creatures almost exactly half way between true reptiles and true birds. Though they had feathers and hollow bones like birds, yet their long tails and toothed jaws and other characters were wonderfully reptile-like. And as the ages went on these creatures were to become more and more bird-like, until at last out of the early reptiles of the sea there were to be developed the true birds which we see on the world today. The unmistakable evidences which the rocks contain of the steady development throughout the ages of the present complex and perfect forms of life from the very simple life of the earliest times is the most wonderful and interesting part of the whole study of geology.

THE AGE OF MAMMALS.

During the latter part of the age of reptiles the whole western part of our continent was elevated, and the bottom of the great sea which until then had stretched from the Gulf of Mexico to the Arctic Ocean and divided our country into two separate parts became dry land. And similar upheavals of land were occurring in many other parts of the world: the close of the last age was a time of continent making, and with the appearance of the great continents, or land regions, a new form of life began to be wonderfully developed. The great reptiles gradually disappeared, but the few warm-blooded land animals steadily increased in numbers and developed wonderfully in form and size, until at last they became the rulers of the world.

The remains of these animals are found in caves, called Bone Caverns, in marshes and peat bogs, in frozen soils and ice of the north, and on old beaches, where, after dying, the animals were stranded. The greatest number are found in the caves, where there are great quantities of bones of all sizes, from those of the elephant to those of rats. The smaller bones are often gnawed, showing that the great mammals carried the smaller ones here to devour them; at last they themselves died and their bones were preserved by the coating of lime which formed above them. Here there are found the great Irish Elk, the enormous Cave Bear, the Cave Lions and Hyenas, both very much larger than the lions and hyenas of the present day, the Sabre, Toothed Tiger, and also the bones of elephants,



1. The Mammoth as it appeared when on earth. Note the long hair and tail and the enormous tusks. 2. Skeleton of a Mammoth from Indiana; now in the American Museum of Natural History.

rhinoceroses and hippopotamuses, and of other animals which still live on the earth.

In this age there roamed over the land the great Mastodon, the Giant Ox and Antelope, each as large as elephants, and many other enormous creatures which have now vanished from the earth. It was truly an age of wonderful mammals. But toward its close there occurred the Glacial Epoch, and under the violent changes produced by the many advances and retreats of the great ice sheet nearly all of these great creatures disappeared forever from the earth.

THE AGE OF MAN.

And last of all we have the age in which we live today—the Age of Man. The gigantic reptiles and mammals have passed away, and no longer is the earth ruled by fierce and terrible creatures. It has become fitted for the dwelling place of a far higher creature than these—one who thinks of the rights and feelings of other living beings beside himself, and who rules by the power of his mind and not by brute force alone.

Just as the first reptiles began to appear in the coal age, and as some mammals were to be found toward the close of the age of reptiles, so we know that early man lived in the age before our own. His bones are found mingled with those of the cave bear and the cave lion and other creatures, and on a piece of reindeer horn which was found in a cave in France there is even seen a rude drawing of a mammoth made by some early man who lived long before the first traces of our written histories begin. But the very earliest traces yet found are those of an entirely and distinctly human creature. The earliest skeletons are those of well-formed men who, though doubtless true savages, were no lower in intelligence, and probably not so low, as many of the savage peoples which live on the world today.

CHAPTER XXVII.

Mountains, Plateaus, and Volcanoes.

GREAT MOUNTAINS WHICH RISE ABOVE THE CLOUDS.

THE hills and mountains of the world are well scattered over the various continents and islands. Some of them are so high that their tops are always covered with snow, and their tops are often lost above the clouds. Some have their bases near the level of the sea, while others rest on a high plateau, but wherever they may be, they tell a tale of the earth's history, and their lofty tops beckon us to explore and unfold the mystery of their birth.

In Asia there are found the highest mountains of the whole world. The highest peak of all towers no less than five and one-half miles above the sea; this is one of the summits of the mighty Himalaya Mountains, which for a distance of twelve hundred miles form the northern frontier of India. The peak is the highest of a wonderful snow-capped group of which many are more than twenty thousand feet high, and it is so very difficult of approach that so far no explorer has ever reached its summit. Most of the passes over the mountains are more than sixteen thousand feet above the sea and commerce across them is very difficult. At this great height the air is so rarified that both animals and man have difficulty in breathing it. At such heights you would breathe very quickly, or "pant" and you could climb only a short distance before you would become exhausted and have to rest.

To find the highest peak of the western continent,

FUJI FROM YOKOHAMA.—The highest mountain in Japan. Its snow-clad summit reaches the height of 12,392 feet.

we must go below the equator to South America, where in Argentina there is a great mount called Aconcagua, nearly four and one half miles high. This has been explored to the very top. The North American continent reaches its highest point in the snow fields of Alaska. Here Mount Saint Elias rises to a height of eighteen thousand feet, while Mount McKinley is more than twenty thousand feet in height. Mount Whitney in California measures fourteen thousand five hundred feet, and this is the highest point of ground within the United States.

On the island of Japan there is a most beautiful and celebrated peak called Fujiyama, which although not remarkable for its very great height yet rises in solitary grandeur more than twelve thousand feet, and with its beautifully curved sides and snow-capped top has ever been an inspiration to the artists of Japan. This mountain was once a great volcano, but it has been perfectly quiet ever since the year 1708.

In the great continent of Africa there are many high mountains, one of which, named Ruwenzori, lies almost exactly on the equator. If you should wish to explore this you would first have to make your way through a dense tropical jungle filled with its wild animals until you had climbed to a height of eight thousand feet. Then for six thousand five hundred feet farther you would find a region of trees and swamps, and when you had passed these you would come at last to the great rock-ribbed top and to the region of perpetual snows. Here you would be no less than sixteen thousand feet above the tropical land from which you started.

In the Antarctic continent there is a great mountain called Mount Erebus which rises thirteen thousand feet above the sea. This is a volcanic mountain. Steam continually escapes from its snow encrusted crater, around which nothing but thousands of miles of polar ice and snow are to be seen in all directions.

DESERT PLACES WHERE PLANTS CAN NOT GROW.

We have seen how the surface of the earth is always acted upon by water, frosts, and winds, all of which are forever changing the face of the land. In some places one of these forces is the most effective and in other places another. For instance, in a warm, tropical country, with almost continual rainfall, water is the chief worker of destruction and transformation; in the great Arctic regions it is the glaciers, while in the northeastern part of the United States it is principally the action of the rains and frost.

In all these regions the wind plays a very small part in the wearing away of the land. But if we think of a rainless region which is subject to intense heat by day and intense cold by night, with very little vegetation to protect the soil, we find the wind an active and important force. We know how a wind that blows clouds of dust along a road does not disturb the soil in the neighboring fields on the two sides of the road, and this shows us clearly how it is that vegetation is a great protection to the soil.

Many people think of deserts as lonely stretches of level sand without life or anything of much interest. Yet they are very different from this. The Sahara desert, the most extensive in the world, stretches across Africa from the Atlantic Ocean to the valley of the Nile River, and from the Sudan on the south to the Mediterranean on the north. It has an area two thirds as great as that of Europe, and is so large that if it were placed upon the United States it would cover almost all of our country from California to the eastern coast and stretch six hundred miles out into the Atlantic Ocean.

Owing to the dry climate, the alternate heating and cooling of the rocks by day and night has broken them to pieces and the action of the wind has ground them into sand. Here and there this sand is piled into great hills, or "Sand dunes," like those seen along our sea coast. Many of them are five or six hundred feet high. An interesting thing about these dunes is that they are always moving in the direction of the prevailing winds, because the wind continually carries the sand up on one side of them and rolls it down the other. The dunes cover a large part of the desert and give it a rough, hilly appearance. In other places there are long stretches of rocky plateaus where all the sand has been blown away. There are also mountains and numerous oases—spots where there is water and where trees and plants grow in spite of the heat. There are bare hills and valleys, buttes and mesas, which the wind has carved and which resemble the formations of the dry, western parts of the United States that were made by the wearing action of water. The average level of the desert is two thousand feet above the sea, but there is also a small part actually below sea level. Even in the Sahara there are occasional showers.

In the southeastern part of California and the neighboring parts of Mexico there is a desert which was once the upper bed of the Gulf of California, and later (probably six or eight hundred years ago), the bed of a lake formed by the draining of the gulf by the sediment brought down by the Colorado River. The Colorado desert, as it is called, undergoes extreme heat in summer, and sometimes a year passes without a drop of rain falling upon it. Scattered sagebrush and the barrel cactus are the most common forms of vegetation. In Utah, Arizona, and Nevada there are also desert lands.

OASES IN THE DESERT.

An Oasis is a fertile spot in the desert where, because of the presence of water, plants grow and men can live. Nowhere is there a direct rainfall on which man could depend to sustain life. The moisture-laden winds blow into the Great Desert from the Mediterranean Sea, their moisture is condensed and usually falls on the high elevations and mountains, and so when the wind then reaches the desert it has lost all its moisture. It is as dry as a sponge that has been squeezed. But the water may flow down the slopes as ground water, and perhaps after going a long distance below the surface of the ground it may reach a lower level and come out on the desert itself as a spring or river. Even if it does not rise to the surface it may sometimes be reached by sinking a shallow well. The soil is found to be very fertile when it is well watered, so that around these scattered springs or wells a kind of civilization is to be found. In the Sahara there are people who live in tents and wander from one oasis to another. Other people live in crude houses and never go away from the oasis in which they were born. About one-twelfth of this immense desert is covered with oases and in these there dwell no less than two and one half millions of people.

A traveler gives the following description of one of the oases of the African desert:

"A little, green corner fresh and shady, cheered with the song of birds, enlivened by the murmur of waters. The dates waved their elegant plumes high in the air; the pomegranates and fig trees crowded between the columns of the palms; wheat and barley clothed the soil with verdure: the water flowed in every direction and the humid vapors vivified the foliage. One could not help trembling for the little spot: it seemed such a feeble thing in the immensity of the desert, surrounded by desolate plains and menaced by moving sand hills."

Bordering the east bank of the Red Sea is the great desert of Arabia; indeed all of Egypt is much like a long oasis on the banks of the Nile, separating the Sahara from the Arabian desert. El-Jouf is one of the famous oases of Arabia noted for the variety and excellence of its dates; thousands of camel loads of this fruit are sent each year from there to Damascus.

The town, which is about two miles long and one half a mile wide, is almost concealed among the luxuriant date-palm trees. The houses are of mud brick with openings for doors and windows and have flat tops. The water of this oasis is drawn from deep wells in buckets made of skins; camels pull the buckets to the tops of the wells by long ropes, and the water is then poured into ditches and canals which irrigate the date orchards.

HIGH PLATEAUS OF THE WORLD.

Upon the various continents of the world there are many large, level tracts of land called Plateaus, which are elevated considerably above the level of the sea. They may have been built up by successive flows of lava, like the Columbia River region in the northwestern United States and the Deccan Plateau of India, or the adjacent country may have been worn away leaving a table-land, or a region may have been lifted up above the surrounding land by the movements of the earth's crust.

Plateaus which are subject to the action of the wind and rain are worn down and carved, the rapidity of their wearing away depending upon the climate. At one time, stretching along the eastern part of the United States from New York to Alabama, the Allegheny and Cumberland Plateaus rose to a height of two thousand feet. But during the long ages which are passed these plateaus have been changed until they have now become a country of sloping valleys, hills and mountains. Evidence of the old plateau can be seen where the rugged, forested Catskills descend abruptly to the Hudson Valley.

In the west the plains gradually rise from the Mississippi until they merge with the plateaus at the base of the Rocky Mountains, four thousand to six thousand feet above the sea. Passing over the Rockies, with its peaks towering fourteen thousand feet high, the mountains descend to another plateau region from six thousand to nine thousand feet which extends to the Sierras and includes the plateaus of the Grand Canyon region and the Columbia Plateau of Washington and Oregon. The high mountains cut off the rain-bearing winds from the Pacific, and thus make a dry arid plateau, parts of which are productive under irrigation and other parts of which are barren.

The table-lands of Asia occupy nearly two-fifths of the continent and are on a grand scale, rising above the average height of the mountains of Europe. The Himalaya Mountains that enclose and traverse these lands are the highest in the world; the Oriental Plateau of Tibet is no less than fourteen thousand feet above the sea, and so is as high as our own Pike's Peak in Colorado. In these high regions wheat, barley and fruits ripen at an elevation which even on the equator would be above the region of perpetual snow. Portions of the plateau are barren deserts, while a considerable part is covered with grassy mountain Steppes, which offer feeding land for many thousands of goats, sheep, and cattle. There are many lakes in this plateau, some of which are salt.

The whole of Africa is a table-land which rises almost directly from the coast to an altitude of from five hundred to two thousand feet. In South America there are some remarkable stretches of table-land or high valleys. The Desaguadero Plateau in Bolivia, twelve thousand nine hundred feet above the sea, is from thirty to sixty miles wide and lies between two parallel chains of the Andes. The northern part of the plateau is populous; the modern city of La Paz, often called ''The City of the Clouds,'' is upon it, not far from the southern shores of Lake Titicaca. Ancient ruins are also found here which tell us that the plateau has been the abode of man for centuries.

MOUNTAINS WHICH POUR OUT STEAM AND MELTED ROCK.

When we look at a single high mountain, standing alone with its gracefully curved sides covered part way up with forests, and its conical top glistening in a mantle of perpetual snow, its beauty and isolation create in us a desire to know something of its origin. It is very different from the mountain ranges we know, with their long, rugged ridges and numerous peaks. Most of the mountains of the earth have been formed by the crinkling and folding of the earth's surface, like a piece of stiff paper crushed in the hand, but in the neighborhood of the mountain chains, and generally scattered parallel to them, these remarkable, isolated mountains are often found.

It is known that these solitary mountains have been formed from material which was thrown out from the earth's interior by some violent force through some crack or opening in its surface. It has taken a great many years and a great number of eruptions to build up these high mountains of which there are many hundreds on the globe. They are called Volcanoes, and many of them are still active, though not so active as they once must have been. Others show a steaming top or crater, sometimes filled with red-hot molten rock, and still others stand cold and dead with their fires banked and no visible signs of activity.

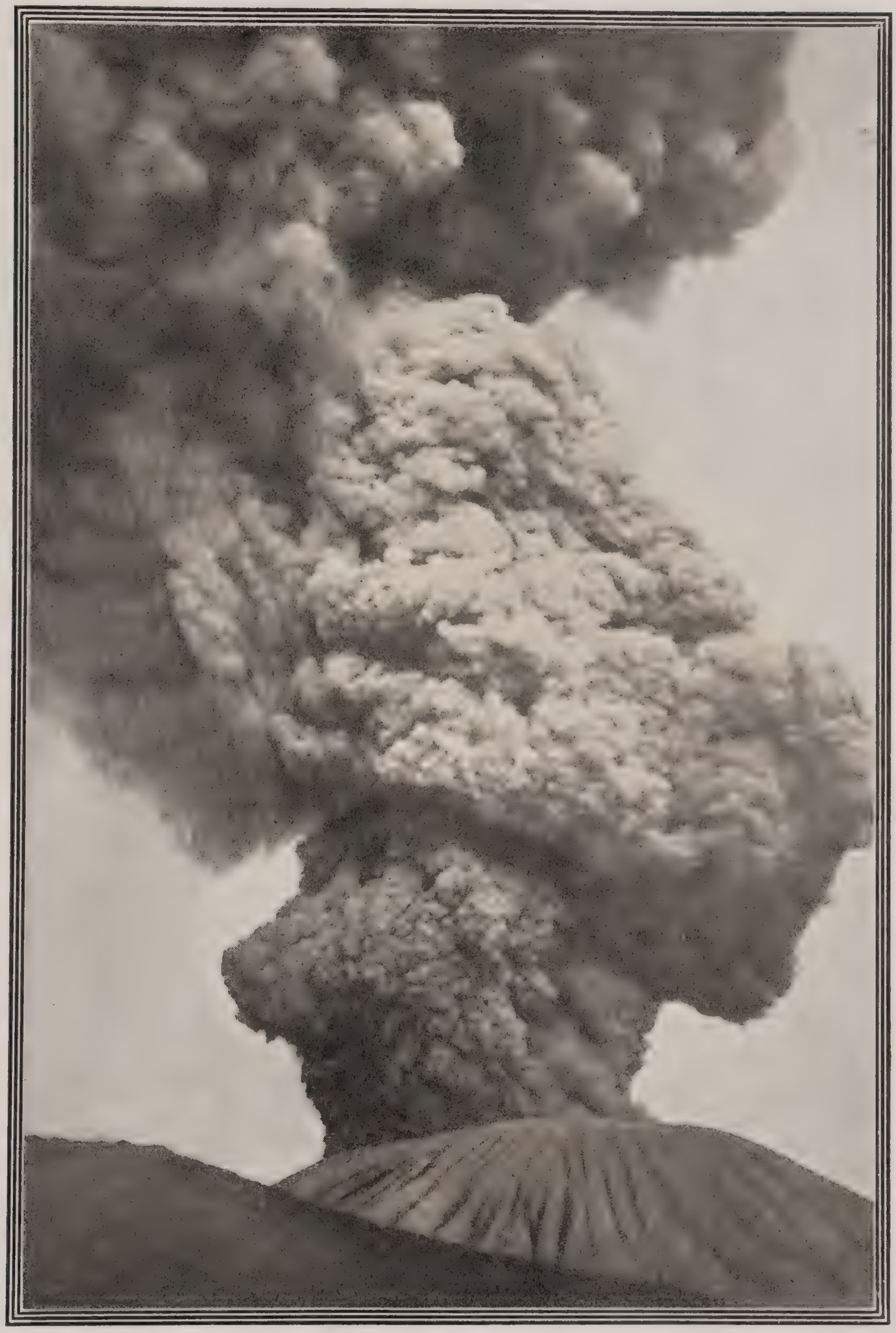
From a study of the active volcanoes, geologists have learned that it is the wonderful explosive power of steam that has driven the stones and ashes to great heights above the top of the mountain during an eruption, and made the heavier material, called Lava, to flow through the cracks and spread down to the lands below. For at the time of an eruption the top of a volcano is covered with an enormous cloud of steam, and lava streams smoke with steam also. At night this steam cloud often reflects the light from the red-hot lava in the crater below, and the mountain appears as if it were all on fire, while the scene is made still more terrible by the vivid flashes of lightning which may be seen playing among the clouds of steam. From the vents and cracks, fumes of various gases are continually pouring out, especially the stifling gases from sulphur. All that is driven out of the volcano, whether it is ashes or stones or molten lava, is nothing but rock which has been melted in the earth's interior. And it is this which has been piled up above the surface of the ground to form the great mountain which we see.

THE GREAT VOLCANO OF KILAUEA.

Those volcanoes which have been built up by the terrible explosions that in past times have driven the powdered rock and ashes to an immense height have generally very steep sides. They are indeed nothing but a great pile of this material which has fallen down and built up a steep mound after having been blown upward into the sky. But on the other hand there are some volcanoes that have been quite quietly formed, and we can always recognize these because they have gently sloping sides and broad bases in proportion to their height. These volcanoes have been built up by gentle flows of great seas of lava which traveled a considerable distance from the opening before it finally became solid. When cooled, this lava resembles the slag and clinkers of a blast furnace.

Some of the finest types of these quietly flowing lava mountains are found in the Hawaiian Islands. One of the most famous is Mauna Loa, a great mountain rising fourteen thousand feet above the sea and whose base is sixty miles across. Beside the main, great crater on the top of this mountain, there is another active crater called Kilauea, ten thousand feet below the summit. This crater is a wonderful thing to visit. From the top of its rim one first climbs down an old lava wall for two hundred feet or more, which is covered with a kind of vegetation; then he passes down a gentle slope of another hundred feet and finds himself on the floor of the crater itself.

This floor is about nine miles around. At times



THE GREAT VOLCANO, VESUVIUS, DURING AN ERUPTION.—The cloud seen rising from the crater is composed of steam and of finely powdered rock which has been ground to pieces by the enormous forces in the earth's interior.

travelers have seen it nothing but a wonderful, hot sea of boiling lava, but in recent years it has become crusted over, so that visitors can walk upon its hardened surface. The fumes of sulphur and the heat from the cracks as one passes by them are evidences of the great hot sea of lava beneath. Scattered over the floor of the crater there are sixty or more small cones, fuming and steaming and exposing the red-hot lava through the cracks on their sides. At one end of the crater is the "Lake of Fire" which is about one thousand feet across, and is nothing but a boiling mass of liquid lava that beats against the hardened sides like waves of water. From the center of the lake, jets of red lava are thrown up, often to a height of forty feet, and they then fall back with a dull, heavy splash. The whole forms a most grand and wonderful spectacle.

At night, from the outer rim of the crater, the scene is still more terrible, for then each of the sixty cones appears as a red, smouldering fire. At the time of the eruption of 1840 a most wonderful thing happened. The main crater was then filled with molten lava to a depth of five or six hundred feet and this immense, hot sea broke through the mountain and in two days made its way to the sea which was forty miles distant. Here in a terrible stream of fire no less than half a mile wide it poured over a great precipice fifty feet high into the ocean below. This wonderful flow lasted for three weeks and heated the waters of the ocean to a distance of twenty miles from the shore.

KEEPING WATCH OF VESUVIUS.

Although one can now go quickly and comfortably by carriage and electric road from Naples to Vesuvius, and can be conducted by guides to the very edge of the crater, this does not indicate that the famous volcanic cone of Italy is no longer very dangerous. No doubt its fires are gradually dying out, and we shall probably never again have another terrible eruption like the one which destroyed the cities of Herculaneum and Pompeii nearly nineteen hundred years ago. Yet there are still times when the old mountain wakes up to show what it can do, and when it pours out from the earth's interior enormous quantities of hot stones and lava and steam.

Before the eruption of 79 A.D., the sides of the mountain were covered with vegetation; fields and vines extended to the very top, and even the crater itself was overgrown. No one then thought that Vesuvius would ever again become an active volcano. But suddenly a terrible eruption occurred and formed the present enormous crater, and since then one eruption has come after another, at longer or shorter intervals, and destroyed altogether an immense amount of property and life.

Let us see what happened in April 1906, which is the most recent eruption of any size. First, a beautiful, black cloud of steam, dust and stones was seen to rise from the crater at the top of the mountain. Then, from various points along a crack that extended from the crater down the southern side of the cone, a great river of lava began to flow down the mountain-side; it started about five hundred feet below the crater rim and the greater part of it poured out at a point about half way down the mountain. This wonderful river of fire flowed at first in a narrow stream, but it ever widened as it descended toward the base of the mountain.

On a certain evening, only a few days later, another enormous cloud shot up from the crater to a height of four miles and spread out over the sky. Lightning crackled about the cloud, and suddenly new streams of lava began to flow. These partly overwhelmed and destroyed a town called Boscotrecase, while on the opposite side of the mountain, at Ottajano, there fell a great weight of ashes which were blown by the wind: houses were buried so deeply that their roofs were crushed, and great stones dropped from the sky, destroying many houses and killing many people.

In the hope of finding out more about the cause of these terrible eruptions and so learning to tell when they are going to occur, an observatory has been built high up on the mountain, almost at the very edge of the crater. In the eruption of 1906 the danger from the hot, stifling gases and the falling stones was so great that the observer had to abandon his delicate instruments and make his escape. But just as soon as he could again push his way to the observatory he returned, and found all his instruments uninjured. Two weeks later Vesuvius resumed its quiet state. Both towns destroyed were within five miles of the crater. The fields, pines and palms outside of Naples were covered with a fine volcanic dust and looked as if they had passed through a snow-storm.

Vesuvius has now been watched for more than two thousand years and much is known of its history. But even now scientists can not tell when a new, violent outbreak may occur. It is very much hoped that the brave men who devote their lives to its study from the little observatory so dangerously near its crater may in time learn how to do this, and so be able to give such warning to the people below that their lives and much of their property may be saved. And beside this, the continued careful study of this one great volcano will teach us much about the terribly great forces ever at work in the interior of the earth.

WHAT HAPPENED WHEN A CITY FULL OF PEOPLE WAS BURIED.

The most destructive and terrible eruption of this great volcano was the one that occurred in the year 79 A.D.—nearly nineteen hundred years ago. Before this time there flourished at the base of the mountain and on the shores of the beautiful Bay of Naples the city of Pompeii, which contained about thirty thousand people, while higher up on the side of the mountain there was the town of Herculaneum, a kind of suburb of Pompeii and which was filled with beautiful homes. People then lived on the slope of the mountain and planted their vineyards far up its steep sides without a thought of danger. For in the course of seventy-five or one hundred years the old lavas had become pulverized and made into a most fertile soil, and vines had even grown over the top of the crater itself.

For five hundred years there had been no signs of any eruption. But about ten years previously frequent and severe earthquakes had begun to be felt along the Bay of Naples. And yet no one seems to have thought how these tremblings of the earth were warnings that great changes were going on in the earth beneath their feet, and that still more violent changes might be expected to come at any moment. Suddenly, without any further warning, a wonderful cloud arose from the crater of Vesuvius. It grew and spread out like an enormous pine tree, blotting out the light of the sun, so that in all the country around it became as if it were night. Earthquake shocks increased in violence. The forces at work within the volcano were so powerful that the ejected material was ground to ashes and dust and carried aloft through the crater by the steam, to fall upon the doomed cities below. The dust and ashes covered a circle of country no less than twenty miles across to a depth of twenty feet. About one fifth of all the people who were within this region were killed, overcome in some places by fumes of poisonous gases which were blown down from the crater, and, in others, smothered and buried deep under the great blanket of hot and stifling ashes. Many of the people had time to seize their more valuable goods and to flee from their homes, never to return; many others who might have escaped were killed as they delayed to gather their money or other valuables, and a few who had actually gotten safely away returned for more of their property and so perished. We can get no better idea of this terrible night of destruction than by reading what one has written who actually saw it all:

"By this time the murky darkness had so increased that one might imagine himself abroad on a black and moonless night, or in a chamber where all the lights had been extinguished. On every hand was heard the complaints of women, the wailing of children, and the cries of men. One called his father, another his son, and another his wife, and only by their voices could they know each other. Many in their despair begged that death would come and end their distress. Some implored the gods to succor them, and some believed that this night was the last, the eternal night which should engulf the universe. Even so it seemed to me—and I consoled myself for the coming death with the reflection: Behold! The world is passing away."

No lava flowed from the mountain during this eruption, but the steam condensed and poured down torrents of rain upon the ashes, making a kind of volcanic mud which flowed into the lower parts of the cities. Although Pompeii did not suffer much from later eruptions, Herculaneum, which is close to the crater, is at the present day buried deeply by ashes and many sheets of lava. Some of the museums in our large cities contain models of the excavations which were made of these buried cities, and these give us a clear idea of the civilization and life of these early people. The colors of the interior decorations of some of the houses are wonderful in their brightness and clearness, after having been buried for more than eighteen hundred years.

KRAKATOA, THE ISLAND THAT BLEW UP.

In the strait of Sunda, which is between Sumatra and Java, there lies a small island seven miles long and five miles wide, called Krakatoa. This island is probably exactly at the meeting point of two lines of fracture of the earth's crust so it is not strange that it has become associated with one of the most appalling volcanic eruptions that has ever happened on the earth. Although Krakatoa was known to be a volcanic island, it had not been seen in eruption for more than three hundred years. But in August, 1883, either because the island was lowered or because of some disturbed condition of the earth, a great current of water flowed from the strait through fissures or cracks in the rock of the earth and inundated the intensely hot strata underneath. Instantly an inconceivably great amount of steam was formed, and its terrible explosive power, not being able to find relief through the vent, actually blew the whole mountain to pieces. The whole lower portion of the land, forming no less than two-thirds of the island, was blown completely away, and thus there was formed a new volcanic crater, deep below the waves.

The sound of the explosion could be heard for a distance of three thousand miles, and the earth's atmosphere was put into a tremendous commotion. The waves set up in the air traveled around the earth many times, and the water around the island was so violently agitated that its waves, traveling four hundred miles an hour through the oceans, surged in all directions away from the disturbance. Tide Gauges, which are instruments for recording the rise and fall of the waters of the sea, showed a sharp rise and fall of the whole ocean, even so far away as on the Pacific coast of North America and on the shores of Europe. Along coasts that were not so far away, the sea rushed over the land in a wall of water fifty to eighty feet high, bringing destruction to all life and property. Yet, very strangely, those ships that were in the straits themselves were but little disturbed. Doubtless they were lifted up to an immense height, but as the whole of this part of the ocean was lifted up with them they were not buried under the waters. At the instant of the explosion, steam, dust and ashes shot up to a height of twelve or thirteen miles above the island and spread out over the heavens in a great cloud. The finer particles were carried completely around the world by the currents in the upper air, and in all countries the atmosphere for many months was filled with dust. It was this dust which produced the beautiful red sunsets and sunrises which all who lived at that time will remember, and even at mid-day the sun was seen to be surrounded by a faint halo of light. In the course of time nearly all of the particles settled slowly to the surface of the earth and our atmosphere became clear again.

OLD VOLCANOES OF THE UNITED STATES.

Starting from Alaska there is a long line of old volcanoes which extends along the entire coast of the North and South American continents. Except in Alaska, there are no volcanoes now in eruption north of Mexico, but in Mexico, Central America, and South America, their activity seems unabated. The volcanic mountains of the United States are to be found near the rim of the great basin which is bounded by the Sierra Nevada and the Rocky Mountains. This is a region of desert plains which was at one time covered by lakes, all of which have disappeared except the Great Salt Lake of Utah. In Colorado, California, Arizona, New Mexico, Idaho, Oregon and Washington there are found many volcanic cones which show us how in earlier times there were here great erupting volcanoes in our country. Thus Mount Caputin, in New Mexico, is a cinder cone nine thousand feet high, and within twenty miles of this many smaller cones, called Monticules, can be found. On the Zuni plateau in Arizona beside Mount Taylor there can be seen numerous volcanic "necks," or old craters from which the ejected cinders have been washed leaving the base cores standing in the plain. In Wyoming there is one of these necks which rises eleven hundred feet above the plateau on which it stands. In these cases the action of the winds and rain has been able to wear away the softer cinders but it has had very little effect on the central, rocky core of the volcano.

Twelve miles from Flagstaff, Arizona, are the beautiful, snow-tipped San Francisco peaks, rising five thousand seven hundred feet above the plain, and wooded almost to their very summits. About two hundred and thirty miles east of these peaks is a great lava field twenty thousand square miles in extent, in which there are many volcanic rocks. Some of this lava has cooled slowly and formed a kind of dark colored, natural glass, from which the Indians used to make their arrow-heads. Mounts Shasta (in Oregon), and Adams, Baker, and Ranier (in Washington), are some of the most wonderful of extinct or slumbering volcanoes. They have never erupted in historic time, and yet it is quite possible that some time in the future some of them may again unexpectedly break out, just as Vesuvius did nearly two thousand years ago. The top of Mount Hood is often encircled with clouds and mist which have the appearance of steam, as if the dead volcano were in quiet eruption. Beautiful Mount Shasta rises fourteen thousand three hundred and fifty feet above the sea, topped by a crater a mile in diameter and one thousand feet deep. Glaciers move down its snowy top toward the plain below.

Beside these many extinct volcanoes, many extensive lava fields are to be found in our country. There is no evidence that in past times this lava poured out of any one single point of eruption, but it is thought that it flowed from the interior of the earth through great cracks of fissures that are now concealed. In the Columbia River region the lava has covered an area of two hundred and twenty five thousand square miles, thus forming the great plateau of Idaho, Washington and Oregon. Layer after layer of lava must have flowed out of the great cracks, for in the great canyon of the Snake River, which is four thousand feet deep and fifteen miles long, equalling the canyon of the Colorado except in coloring, there can be seen three thousand feet of the hardened lava, or Basalt, the same material of which the Palisades along the Hudson are formed. But some at least of this great sea of lava may have flowed from Shasta and Ranier when these volcanoes were active. Upon this lava plateau there are raised today some of the finest fields of grain in the west.

CHAPTER XXVIII.

The Cause of World-Shaking Earthquakes and of Mountain Formation.

WHERE THE GREAT MOUNTAIN RANGES OF THE WORLD ARE FOUND.

AMONG the most important phenomena of the earth's surface are the great mountain ranges which usually traverse the margins of the continents and run nearly parallel to the sea. It is these mountain ranges which fix the drainage of the great river systems of the world, and thus determine the inland navigation of the several continents. Moreover, these elevated ridges of the earth's surface usually become the political boundaries of the different countries adjacent to them. It is only recently that the highest mountain ranges have been explored, and even now but few of the mountain systems are pierced by railroads, the packmule and similar beasts of burden being the chief means of transportation over these passes and plateaus. And when a railroad has been cut through a range, such as that now piercing the Andes near Aconcagua, connecting Chile with Argentina, the cost of shipping over these high regions is so great that most of the commerce of the world goes by sea or by rivers leading to tide-water.

Thus the mountains and plateaus of the world are so important that in any general view of the earth we ought to inquire into their mode of formation. For a long time this inquiry was beset with extreme difficulty; but after the great earthquake at San Francisco in 1906, we had occasion to treat the subject with care, in four memoirs, published in the Proceedings of the American Philosophical Society, held at Philadelphia, and were thus enabled to discover and prove the true cause of Mountain Formation.

For about a century geologists had held that mountains are wrinkles in the earth's crust, due to the shrinkage of the globe. This old theory is still given in the books used in our schools, but it is now questioned, and in fact entirely abandoned by many progressive investigators. The shrinkage theory always encountered great difficulties in explaining the parallelism of mountains to the seashore, which is the most striking feature of terrestrial geography.

TWO GREAT EARTHQUAKES.

It was proved by exact calculation that the shrinkage in the earth's radius, due to loss of internal heat, is only 1.5 inches in two thousand years, whereas in world-shaking earthquakes, the sea coasts of certain regions frequently are uplifted bodily to many feet in a single disturbance. Thus, in the great earthquake at Yakutat Bay, Alaska, September 3-20, 1899, the sea coast was uplifted for more than a hundred miles, the maximum uplift being forty-seven and one-third feet. In a few places subsidences also occurred. During this great disturbance the shaking of the earth was so violent that some travelers who witnessed it could not stand on their feet, but had to lie flat on the ground. Great glaciers were shaken loose and slid into the bay, while the sea was violently agitated and thrown into great waves which swept along the shore and tore up the forests.

This earthquake was especially investigated in 1905 by Prof. R. S. Tarr, of Cornell University, and Mr. Lawrence Martin, of the National Geographical Society, who secured photographs of the uplifted coast, with barnacles still sticking to the rocks nearly fifty feet above high tide. The fact of the uplift of the coast is thus beyond doubt, but other uplifts are nearly as well established.

The Alaskan earthquake is similar in character to many which have disturbed the Western Seaboard of South America during the last two centuries. In many of these Chilean and Peruvian earthquakes the coast has been uplifted and afterwards inundated by seismic seawaves. Thus, on August 13, 1868, the town of Arica was laid waste by a terrible earthquake, which disturbed the coast for hundreds of miles. Soon after the earthquake the officers of the ships in the harbor were surprised to notice the water withdrawing from the shore, leaving the sea bottom exposed or covered by shallow water. Whales and other monsters of the deep floundered around in the newly-formed lagoons and could scarcely escape to the sea; while vessels which had been anchored in seven fathoms of water now rested on the bare ground, as helpless as fish on dry land.

Among the vessels thus helplessly stranded were the United States ships *Wateree* and *Fredonia.* The surprise of the officers on witnessing the gradual withdrawal of the sea from the shore, however, was a little later converted into terror when they saw in the distance a great wave returning with terrific speed and carrying everything before it. The helpless ship *Wateree* was picked up by the great wave like a chip and carried nearly a mile inland, where it was landed safely on the beach, like Noah's Ark on Mount Ararat, after the deluge; but the unfortunate *Fredonia* seems to have capsized and was never again heard of, all on board being lost.

The wave which swept the shore then again receded and left the sea-bottom dry as before, but in half an hour or so it returned and again swept the shore, as in the first inundation. The periodic motion of the sea thus started continued for some time, and it was several days before the troubled waters entirely subsided. Meanwhile great numbers of ships were washed ashore or destroyed, and the coast devastated for hundreds of miles. This earthquake occasioned the most terrible disturbance of the sea recorded in the annals of South America.

WHAT CAUSED THE GREAT WAVES FROM THE SEA.

Now let us consider the meaning of this great wave and the repeated oscillation of the waters which proved so disastrous to the coast towns and to shipping. As the water drained off from the shore immediately after the earthquake and left the ships resting on the dry bottom, where there was forty-two feet of water only an hour before, it is evident that the sea bottom must have sunk over a large area some distance from the shore. This drop in the sea-bottom caused the water to rush in from all sides to fill up the depression in the sea-level over the sunken area; and thus it was drained away from the shore and the ships settled and became stranded where they rested at anchor.

By the force of the currents setting towards the center of the sunken area, the normal level would not only be restored, but finally an elevation or ridge of water forced up over the sunken area; and as soon as this elevation of water reached its maximum height, it would begin to collapse under its own weight; and then a wave would develop and travel towards the shore. This is the so-called "Tidal Wave," or more properly the seismic sea-wave, which washed the *Wateree* inland and caused such a terrible inundation of the coast.

The outward movement of the water would make a second depression of the sea-level over the sunken area, and the water again rush in from the shore to fill it up, and this is the second withdrawal of the water from the sea-coast, to be followed later by a second seismic sea-wave a little smaller than the first.

The oscillations of the sea caused by the sinking of the sea-bottom thus continued till the disturbance died out by the effect of friction of the water against the bottom, as it rolled back and forth from land to sea and *vice versa.* The great waves thus generated by the sinking of a part of the sea-bottom off the Peruvian coast in 1868 were propagated all over the world and registered on the tidal instruments in the United States, Europe, Japan and India. By noting the time the wave takes to travel across the ocean, mathematicians were enabled to calculate the average depth of the Pacific Ocean; which was very useful knowledge in the days before we learned how to measure the depths of the sea by sounding-apparatus, such as is now available for surveying the routes for submarine cables.

WHY THE BOTTOM OF THE SEA SINKS DOWN.

The seismic sea-wave being thus explained, let us inquire into the meaning of this sinking of the sea-bottom. As these seismic sea-waves often occur in great earthquakes and are of the same general type, they must be due to the same cause, namely, changes of level in the sea-bottom. The bed of the ocean usually sinks, but in a few cases it is upheaved, and a wave then rushes ashore before the water backs off and lays bare the bottom. Both types of waves occur in earthquakes. The sinking of the sea-bottom is prevalent along the western coast of South America, and has given rise to a trench of unusual depth, parallel to the Andes; so that if the mountains were dug off by a mighty engine and thrown into the ocean, they would about fill up the trench. It was the noting of this fact that enabled us to see that the mountains are really formed by the expulsion of lava from under the bed of the sea. The great earthquakes are due to the movement and adjustment of streams of molten rock beneath the crust of the globe; and it is this movement of the underlying rock which shakes the overlying crust so terribly that cities and houses are reduced to ruins and whole provinces laid waste.

Even the Greeks suspected, two thousand years ago, that in earthquakes matter was moving beneath the crust, for they compared the shaking of the earth to the tremors produced, on a small scale, by a mole when it burrows in the ground, and violently agitates the soil just over its path. This is indeed one of the best comparisons that has been given of earthquake phenomena. The burrowing of a mole in the ground is a phenomenon familiar to nearly every one, and the shaking which we notice by the underground movement of this small animal we witness on a vast scale in earthquakes, where lava streams are adjusting themselves under the earth's crust. No wonder rocks are rent asunder, mountains and volcanoes uplifted, and the sea-coast raised for hundreds of miles.

Again, it was remarked by Aristotle that earthquakes are especially prevalent in maritime regions. We now know the reason of this well-established fact: namely, the ocean bottom leaks, and the gradual accumulation of steam in the underlying lava causes it to swell, and when the pent-up force is great enough, a yielding occurs and lava is expelled from under the sea and pushed under the land.

HOW MOUNTAIN RANGES ARE FORMED.

Accordingly the uplift of the sea-coast so often witnessed in South America means that some additional lava is pushed under it; otherwise it could not be upraised. And the sinking of the sea-bottom implied in the withdrawal of the water just before the great seismic sea-wave rolls in upon the devastated shore, means that the bed of the ocean has been undermined. As the sea-bottom sinks, while the coast is uplifted, the shaking of the earthquake is nothing but the disturbance of the surface, due to the transfer of lava from the sea and its injection under the land. In this way the Andes were raised from beneath by matter expelled from beneath the border of the Pacific;

so that these mountains are really a wall which the ocean has erected along its margin. A wonderfully simple and general theory which enables us to understand why the mountains follow the borders of the continents.

The new theory is confirmed not only by the observed uplifts of the coasts, and the sea-waves noticed to accompany the greatest earthquakes, but also by the location of the active volcanoes along the borders of the continents. No volcanoes remain inactive less than about one hundred miles from the sea. When we remember this fact, and recall that 999 parts in 1,000 of all the vapor emitted by volcanoes is steam, we see that the volcanoes are really vents or valves through which the underlying steam pressure often finds release.

The Greeks and Romans living near Vesuvius and Ætna noticed that the earthquake shocks usually abated after these volcanoes suffered eruptions and their imprisoned vapor escaped into the atmosphere; and Humboldt found that the inhabitants of the Andes likewise held that the volcanoes of that region acted as safety valves for the escape of imprisoned vapor, which otherwise would occasion terrible shocks. It is obvious that these views, independently adopted by the most distant races of mankind, rest upon a substantial basis of truth; and now we find that the mountain-forming forces are identical with the forces producing volcanic action. The difference is that, in the latter case, there is a vent and the steam escapes, whereas in mountain-making the imprisoned vapor often remains hidden in the earth, and is scattered or absorbed. This is confirmed by the fact that mountains in eruption often blow out pumice, which is simply molten rock inflated with steam and dried. When this porous rock is broken and ground up, it forms a cloud of dust, which is the ''smoke'' noticed to issue from volcanoes.

From this line of argument it follows that the mountains of the earth are produced by the expulsion of lava from under the bed of the sea. In some cases the older mountains are now far inland, but they were once nearer the sea, the contours of the oceans having contracted by the gradual growth of the continents in the course of immense ages; so that in considering the different mountain ranges, we have to trace out the ancient outlines of the continents. Accordingly as the mountains are formed by the sea, we thus have a new method for improving the science of geology and studying the growth of the greater areas of land.

It has been noticed for nearly two hundred years that some mountains attract the plumb line as if they were hollow and that the plateaus seem to be underlaid with material which is lighter than the average of the earth's crust. This is now explained by the steam-saturated lava pushed under these masses from beneath the ocean, thus giving them a lining or substructure of pumice or porous material lighter than the average rock of the crust of the globe.

We must now add a few words regarding the formation of the great plateaus of the earth. We begin with the plateau of Titicaca, in Bolivia, because its formation is simple and admits of no dispute. It being admitted that the Andes were uplifted by lava expelled from under the ocean, we naturally ask whether the plateaus of these great mountains could have arisen in the same way. Obviously they could. For the plateaus of Titicaca, Cuzco, and Quito are so embraced within the different ranges of the Andes that whatever uplifted the one would necessarily have raised the other. Thus the plateaus are but parts of the Andean system, and as the mountains are formed by the sea, it is obvious that the plateaus are also. And the plateaus are so connected with the continents as to lead us to infer that not only mountains, plateaus, and islands may be raised by the sea, but also the continents themselves. The mountain ranges and plateaus are the backbones of the continents and most intimately connected with their formation.

As far back as 1845 the celebrated American geologist, James D. Dana, of Yale University, observed that all over the world the typical arrangement is one in which the mountains follow the borders of the continents, and that the larger mountains and plateaus face the greatest oceans. He believed that there was a connection between the formation of the mountains and the oceans, but could not make out what it was. Now we know why the great mountains face the great oceans, and *vice versa.* The plateaus as well as the mountains have been formed by the uplift of portions of the earth's crust, through the expulsion of lava from under the bed of the sea. Naturally this cause has been most powerful along the borders of the greatest oceans, and hence it is that what is called the World Ridge runs around the bodies of the Pacific and Indian oceans, while the mountains along the smaller oceans are correspondingly insignificant in size and height.

This is the culmination of our argument as to the formation of the great mountain systems of the world. The very face of the earth shows that the mountains are formed by the sea, and not by the shrinkage of the earth, as so long erroneously taught in geology.

In the case of the Aleutian Islands we have a mountain range still forming in the water and not yet raised above the sea. A deep trench is being dug out just south of the Aleutian Islands, as these islands are pushed up into a mighty range. In time the trench to the south will get so deep that the southern edge of it will fold up and give us another range parallel to that already developed. Thus are mountains formed in double and treble parallel ranges.

This explains easily and simply one of the most mysterious phenomena of our earth, which long proved utterly bewildering to geologists and geographers. So direct and simple is the present explanation that the celebrated Italian astronomer Schiaparelli regarded it as one of the most remarkable discoveries of our age. It is indeed difficult to understand why men of science were so slow in finding out the true cause of mountain formation. Misleading traditions, handed down from past centuries, long acted as an obstacle to real progress; but now that the nature of mountain formation is clearly made out, the physical features of the globe become much more intelligible, and the problems of geography and geology appear in a new light of deep interest to all students of Nature.

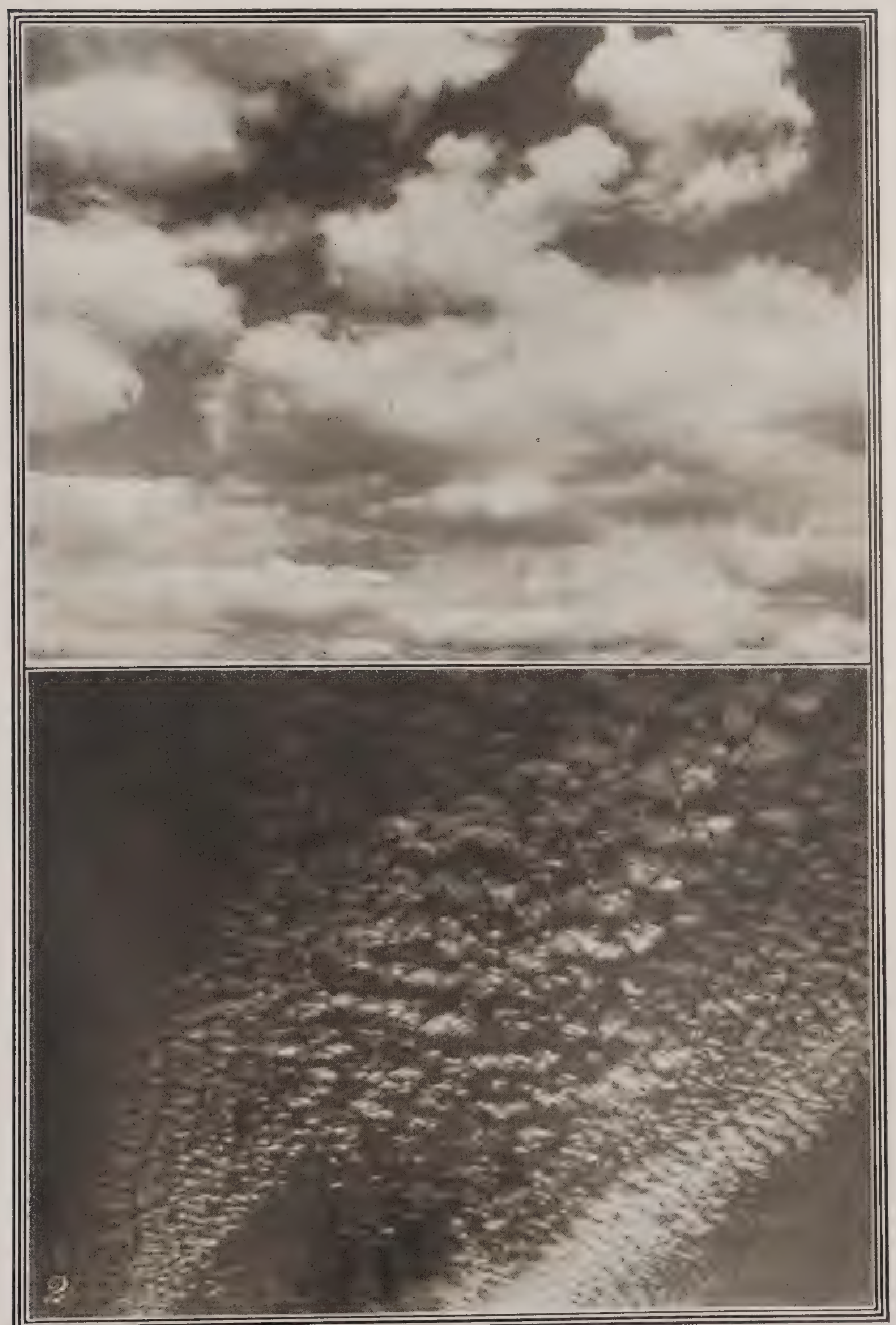
CHAPTER XXIX.

Some of the Things Surface Waters Do.

HOW RIVERS FLOW TO THE SEA.

WE have already seen how all the rivers of the world are great carriers, ceaselessly transporting the rocks and earths of our land to the floors of the sea, where new rocks are being slowly formed which will become the new lands of future ages. But on its way the flowing water often makes great changes in the face of the land itself, cutting deep gorges in some places, forming high water-falls in others, here filling barren plains deep with fertile soil and there ploughing below the surface of a dry desert and flowing afterward underground unseen, until it at last perhaps again emerges to water a distant country by many springs, or perhaps to form great swamps or lakes there. We will therefore tell a little about the most important bodies of water in the world, and will describe a few of the interesting changes which they are bringing about upon its surface.

The power of river water to cut rocks and lands away depends on the amount of water, its height above sea level and the nature of the rocks over and through which it runs. Water is lifted by the action of the sun's heat to form clouds and then may fall as rain or snow on high elevations; the rain or melting snow runs continually off the mountains or hills in small streams which at last may join to form a larger stream. But the water of a larger stream does not come from the surface of the ground alone. There is an immense amount of water always slowly working down each slope, which has soaked down through the soil until it has reached a layer of harder soil or rock, and along



CLOUDS.—The Cumulus; warm weather clouds which form about a mile above the earth. 2. The Cirrus; highest and fastest-moving of the clouds, forming from six to ten miles above the earth.

this it will slowly flow underground until at last at a much lower level it may bubble to the surface again as a spring. The stream, fed both by surface streams and under-ground waters, soon narrows into a channel, the water moving more swiftly and cutting more deeply. Soil and rocks from the sloping sides of the mountain, loosened by rains and frost, may roll into it. Often, as in Switzerland, great avalanches of material, all of which has been loosened and made slippery by the water which has soaked into it from the surface, slide down into the streams.

The swiftly running water pushes all of this material along its bed, which is thus gradually deepened by the grinding action; even the larger stones are finally worn away by the action of the smaller ones hurled against them by the water. These mountain streams flow together and form larger ones, until by a succession of unions there is made a mighty river that is able to cut great canyons out of solid rocks.

Rivers do not generally flow in a straight course, but swing back and forth, alternately cutting the bank on one side and depositing sediment and waste on the other. Some rivers which start out bravely from the mountain top and overcome the difficulties of a long descent, perhaps cutting out a canyon as they go, whither and vanish in the desert sands at the base of the mountain. Other streams drop into sink holes, to flow underground for some distance and finally come to the surface again.

As a result of the powers of rivers, mountains are worn down, and rocks are powdered and spread over plains to form fertile soil. In past times they have made valleys which now form passes across steep mountains and make commerce between different countries possible; their waters by ditches are made to irrigate desert and arid lands, and their waterfalls supply power to do man's work.

THE LONGEST RIVER IN THE WORLD.

The Mississippi River rises in two small lakes on a plateau in Minnesota, fifteen hundred feet above the sea, and flows south into the Gulf of Mexico. It receives so many mighty tributaries, like the Missouri, Arkansas, Red and Ohio rivers, that the original river supplies but a small part of the waters that finally reach the sea through its channel. The whole system drains twenty-eight States, which is half the drainage area of the great Amazon, and no less than fifty-four of its tributary rivers are navigable by steamboat. These tributary streams rise on the west as far away as the Rocky Mountains, and on the east among the mountains of the Appalachian Range, the distance from one ridge to the other being so great as one-eighth of the distance around the whole earth. The distance from the source of the Missouri to the Gulf is forty-three hundred miles: this makes the Mississippi and the Missouri together the longest river system of the whole world.

The Mississippi is a meandering river, swinging back and forth on the floor of its valley, which in some places is eighty miles wide. The curved bends are sometimes from five to six miles straight across. It is so crooked in part of its course that the river takes thirteen hundred miles to cover a straight course of only six hundred and seventy-one miles. It is also continually changing its channel. The river down which La Salle paddled, two hundred years ago, has at various times since been dry land, now on one bank of the river and now on the other. The whole river bed over which this first explorer sailed is now dry land, and farms and towns now lie where once the water was flowing. Once it was known to shorten its course thirty miles at one jump. At such times the down-stream bank is cut to meet the up-stream bank on the lower part of the bend. The abandoned portion of the river in time forms an ‘‘Ox-bow’’ lake, for many of which the river is noted.

The Mississippi grows narrower and deeper as it approaches the Gulf, which is quite unlike most rivers. Just above its mouth it is about half a mile wide and one hundred and twenty-nine feet deep, while at the junction of the Ohio it is eighty-seven feet deep and about one mile wide. Although it has only a slight slope, yet it carries down each year an immense amount of rock waste, some carried in suspension and some swept along its bottom. Great quantities of the material are deposited when the river overflows its banks, but most of it is carried to the Gulf. The Gulf is shallow at the mouth of the river and the tides are weak there, and it is for this reason that the delta is being extended so very rapidly. It has already an area of twelve thousand square miles, many thousands of acres of which are productive land.

THE LARGEST RIVER IN THE WORLD.

The high Andes of South America rise abruptly from the Pacific with a narrow shore plain, and slope on the east into valleys, gorges, and deep ravines through which the torrents rush from the summits of the mountains to the plains below. Here the moisture, borne by trade winds across Brazil from the far Atlantic, falls on the mountain barrier in almost continual rain and supplies the waters for the great river of the Amazon. The winds which descend on the western slope are consequently very dry, for they have left nearly all of their water on the east sides of the high mountains.

Ages ago the whole eastern coast of South America was buried under the sea and a great number of rivers poured at many different places into the ocean. But in time a shifting of the earth's surface lifted this submerged portion of the continent above the level of the sea and then all these rivers of Brazil united their waters to form one mighty system called the River of the Amazons. Three parts of the one great river have three different names. From its source to the mouth of the Ucayli it is called Maranon; from here to its junction with the Rio Negro it is known as Solimoes, and through its remaining extent it is called the Amazon. It receives the waters of two hundred tributaries, one hundred of which are navigable, and several of these are from one thousand to twenty-five hundred miles in length. Its principal sources are the Ucayli and Maranon rivers which rise in the lakes of the Peruvian Andes, twelve thousand feet above the sea. At the point where the two rivers join it is no less than a mile wide and this width increases continually, until when it enters the ocean it has attained the enormous width of one hundred and twenty-five miles.

Although the Amazon carries to the sea five times as much water as the Mississippi does, its drainage basin is less than twice as large. It is therefore not surprising that this part of the earth's surface is being worn away much faster than our great Mississippi valley. At a point three thousand miles from its mouth, its bed is only two hundred and ten feet above the sea, so that the average slope is here less than one inch a mile. As a result the forested banks, or Silvas, are at flood times converted into a great lake. These great tropical forests, ever growing in the rich, wet soil are most striking and wonderful examples of the luxuriance of plant life in the hot regions of the earth. Innumerable tropical insects abound there, the great boa constrictors and other reptiles make their way among the densely crowded vegetation, and in the branches overhead there are innumerable brightly-colored parrots and noisy monkeys and other tropical animals.

The waters of the Amazon empty into the ocean by two channels forming a wide estuary through which the tides enter from the ocean and extend up the river to a distance of five hundred miles. At the larger mouth this tide passes up the river in three or four waves in quick succession from fifteen to twenty feet high.

HOW RIVERS MAKE GREAT CANYONS.

Water when loaded with sand and other materials is quite wonderful in its action, for it is then able to cut deep grooves, or gorges, in even the hardest rocks over which it passes on its way to the sea. If the surface of the earth over which such a river is flowing is being ever so slowly lifted up, then the gorge will be cut deeper and deeper until at last we may have a great canyon whose sides are lifted straight up for many hundreds of feet above the swiftly flowing stream below. And if at this point a slow wrinkling of the earth's crust has been taking place, we may in time see a high mountain range rising on each side of the river and directly through which the river seems to have cut its way. But we must not make the mistake of thinking that the mountain was formed first and that the river was able to cut through it afterward. This it could, of course, never have done; the mountain would merely have changed the course of the water. The rising of the land was really very slow and the river ever cut it away as it was lifted up, at last forming a deep and narrow gap. The beautiful Delaware Water Gap and the gap at Harper's Ferry on the Potomac were cut in this manner, but the sides of these gaps do not extend straight up because the surface rains and frosts have slowly worn their sides away to a sloping position. On the other hand, the Royal Gorge of the Arkansas, which is situated in a more arid climate has walls which rise up almost vertically from the river.

There is a river that rises in the melting snows of the high mountains of Colorado and which after a long journey reaches sea level at the gulf of California. There is a drop of ten thousand feet from its source to its mouth. The melting snows and the rapid descent make a stream which is able to most powerfully cut away the rock. In its course it passes through an elevated plateau built up of almost perfectly level layers of rocks of various kinds. At first the winding stream cut a channel which was very far from straight, for there were no walls to guide it. Owing to the rapidity of the stream and the grinding action of the pebbles and other material in the water the channel deepened rapidly. The sides of the canyon did not widen very fast because of the resisting power of the rocks and the dryness of the climate, and they were but little worn away by surface waters. If the climate had been moist the sides of the canyon would have been gradually washed down into the river and a wider, much less steep, gorge would have resulted.

The great depth of the gorge is also due to the fact that the whole plateau has been slowly elevated. At the same time that the river was deepening its channel many smaller streams were cutting large side canyons away which now enter into the main canyon. The canyon is now two hundred miles long and from five to six thousand feet deep. In many places the river can not be seen nor heard from its rim, but where it can be seen it appears like a beautiful, silver thread at the bottom of the deep gorge. In reality it is two hundred feet wide and a swift, tawny stream. The canyon has been compared to an ''inverted mountain range,'' so wonderful are its dimensions. The horizontal layers which form its sides have the appearance of irregular terraces connected by steep slopes.

Under the bright sun of the dry climate of Arizona, the different layers of rocks give a most wonderful color effect. The narrow gorge in which the river runs has almost vertical walls of granite, some of which are eight hundred feet high. Above this there is a layer of eight hundred feet of quartz, five hundred of sandstone, thirty-six hundred of limestone, and finally there are one thousand feet of white limestone at the very top of the canyon. Through all of this the river has cut. Of the many wonderful sights produced by the action of water in the form of canyons and gorges, this wonderful Canyon of the Colorado is the most magnificent. Yet when we think of the stupendous changes which have been continually brought about in past ages we see that even this is but a very little thing—a mere passing incident in the great geologic development.

THE FALLS OF NIAGARA, AND WHAT WILL SOME DAY BECOME OF THEM.

The United States has the greatest and most wonderful fresh water lake system in the world. Five great lakes remain ever fresh, partly because they are new lakes which were formed in quite recent geologic times and partly because all the surface material that is washed into them does not stay there to make them more and more salt, but is continually drained into the Atlantic Ocean by the Saint Lawrence River.

The two easternmost of all the lakes are known as Lake Erie and Lake Ontario, and these are connected by the Niagara River, thirty-six miles in length, through which the waters of all the great lakes must pass on their way to the sea. It is on this river that the wonderful falls are to be seen. From the eastern end of Lake Erie to the western end of Lake Ontario is a distance of only thirty-six miles, yet in this short passage there is a descent of no less than three hundred and thirty-four feet. The Niagara River rushes down this steep incline with enormous rapidity, for the whole fall in this short distance is much more than the fall all the way from Lake Ontario to the Atlantic Ocean. Here, twenty-two miles from Lake Erie and fourteen from Lake Ontario, the wonderful falls are situated.

Just above the falls is Goat Island which divides the river in such a manner as to form two branches; the waters in the main channel follow the Canadian shore and plunge into a gorge one hundred and fifty-nine feet below, forming the Horse-shoe Falls, while the other branch of the river plunges down one hundred and sixty-nine feet, producing the American Falls. Above the falls the water tumbles among the rocks forming the upper rapids, accomplishing in only six miles a descent of fifty-two feet. Thundering over the falls in a beautiful green sheet, it dashes against the rocks below, causing a mist on which the glancing sunlight often forms a most beautiful rainbow.

A short distance below the falls are the lower rapids; still farther down, the water strikes a bend in the river and produces a whirlpool. From the falls, for a distance of seven miles down the river, the water flows through a rough and deep gorge which the river has slowly carved out of the deep layers of solid rock; when the end of this is reached the river widens and flows through a comparatively level plain to Lake Ontario.

It was at the end of this deep gorge that the falls first began to work backward many years ago, and in the course of these many years they have carved out the great groove, seven miles long, that we see today. On the surface of the ground there is a hard layer of sandstone rock which overlies a softer rock of limestone, and this was slowly worn away, ever farther and farther back, by the wearing action of the water. As the grinding away went on the overhanging hard layer, being unsupported, constantly broke and fell and was ground into pebbles and finer material and transported by the river to be at last laid down in Lake Ontario. In this way the ledge of the falls has ever steadily been worn backward; even now they are receding up the Niagara River a little faster than one foot each year. It is believed that the time required for them to ‘‘back up’’ from the open country seven miles away and to wear out the deep gorge is no less than thirty-six thousand years.

The falls are thus constantly working upstream and making a deep gorge in which the river flows. The greatest volume of water flows over the apex of the horse-shoe and the greatest amount of cutting is therefore done at this point; this may perhaps amount to as much as two feet each year. Wearing back, the falls will slowly move to the end of Goat Island, and when this is worn away the river will no longer be divided: the American falls will then be transformed into a dry precipice and become a portion of the walls of the gorge. After many more thousands of years the falls will retreat to Lake Erie and much of the water of this great lake will then be drained away.

HOW WATER FORMS LAKES.

When a river or stream flows from the mountains to the sea it may reach a point when the waters, because of a natural depression in the earth’s surface, spread out over a larger area, or it may meet a barrier of elevated land, and the course of the river may be obstructed. Then a lake will be formed unless the river can cut through the barrier, exactly as by constructing a dam across a stream we often form an artificial lake or pond.

Whenever a stream flows into a lake its current is checked and a great amount of the material it is carrying with it is deposited on the bottom. Owing to the broad surface of the lake a great amount of water must always evaporate; the amount of water flowing out of a lake is therefore always very much less than the amount which flows into it. For instance, a great deal of the water which is flowing into the Great Lakes never passes out through the Saint Lawrence into the sea. In dry climates all of the water that flows into a lake may be evaporated in this way so that there is no water flowing out of the lake at all. The Great Salt Lake of Utah and the Dead Sea of Palestine are lakes of this kind. As the water evaporates it leaves behind not only all of the material which it is carrying but also all that it has dissolved; these lakes therefore become more and more salt, exactly as the oceans do, and for the same reason.

The natural depressions of the earth which serve as basins for lakes may have resulted from a movement of the earth's surface when mountains were building, or they may have been formed by the glaciers which in past times wore and scraped the land away. It has been estimated that nine-tenths of the basins of the small lakes of the world were made by the action of glaciers. In North America many thousands of lakes were formed in this way of which many have disappeared, although in Minnesota many of these glacier-made lakes still remain.

Some of the highest lakes of the world, and often the most beautiful ones are found in the craters of extinct volcanoes. The vent in the crater from which the eruption took place was first closed by lava and rock, and then the rain water gradually accumulated and filled up the crater. The beautiful Lago Bolsena, south of Rome, which is a lake eight miles across, and the deep, clear, Crater Lake of Oregon are examples of these wonderfully made lakes which now fill with their quiet waters the craters of great volcanoes.

THE LARGEST LAKES IN THE WORLD.

Lake Superior, the first of the chain of five great lakes in the United States, is the very largest body of fresh water in the whole world. It is fed at its extreme western end by the Saint Louis River, a stream two hundred miles long and the largest river flowing into the Great Lakes, but water is also poured into them by many other streams and springs and by the rains and snows. In fact, much more water flows into them than can flow out through the Saint Lawrence River, and yet their level is not rising. The difference is made up by the enormous amount of evaporation that is continually going on all over their great surface of more than ninety-five thousand square miles. Since water when evaporating must leave all of its dissolved and carried materials behind, this unceasing action will if continued long enough undoubtedly change all our great lakes into enormous inland seas of salt water. It is, however, unlikely that this will ever happen. Before a long enough time has passed it is probable that slow geologic changes will have so altered conditions in this part of our country that the present site of these five great lakes will be nothing but dry land.

The Caspian Sea is the largest isolated sheet of water on the globe, with an area of one hundred and seventy thousand square miles and a depth of five hundred feet. It has no outlet and therefore, because of evaporation, its water is salty. Much salt, however, is deposited in the wide, shallow inlet of the lake and on its wide, shelving shores and its waters are therefore less salt than they otherwise would be. It was at one time an arm of the ocean, but changes in the earth's surface have cut it off. At present the surface of the water is ninety feet below the level of the sea.

Victoria Nyanza, of Central Africa, is the largest of the Nile lakes, and second in size of all the fresh water lakes of the world; Lake Superior is the only lake of the world larger than this one. It is two hundred miles long and one hundred and thirty miles wide, and lies nearly four thousand feet above the level of the sea. But the highest lake in the world lies high up in the Andes Mountains of South America, no less than twelve thousand five hundred feet above the ocean. This beautiful little body of water is called Lake Titicaca, or the "Lake of the Clouds."

The beautiful Crater Lake of Oregon, though not very large in area ranks in interest with the Grand Canyon and Niagara Falls. The water from rains and melting snows collects in this old volcanic crater which forms its basin, and forms there a lake seven thousand feet above the sea. Cliffs from five hundred to two thousand feet high surround the sheet of blue, transparent water. The basin does not fill up and overflow, but it must have some underground outlet, and in all the region around its waters come to the surface of the ground in springs. An old volcanic cone rises above the water at one side of the lake and forms a partly wooded island.

WATER IN WHICH MAN CAN NOT SINK.

The most striking example in our country of a lake which has become salty through the continued evaporation of its waters is the Great Salt Lake of Utah. This lake is seventy-five miles long and from thirty to fifty miles wide, and it has an average depth of twenty feet. There are two rivers which flow into it, called the Jordan and the Bear; these supply it with fresh water, but it has no outlet: as it is situated in a high and arid country all the water flowing into it disappears by evaporation. As the evaporating water leaves behind it all the minerals which were dissolved in it, and as the evaporation has continued for a very long time, the water left in the Great Salt Lake is at present a concentrated brine. If we place five gallons of it in a pan and heat it on a stove we find that it leaves behind no less than one and one-half gallons of salt. In consequence of this the water is very much heavier than fresh water. Wading in the lake is difficult, and when one tries to swim in it he finds that his body will not sink—very much of his body is lifted above the heavy water. When he comes out of the lake his body soon dries, but his skin is left very rough and uncomfortably covered with salt. Sailboats built for fresh water would be top-heavy and quite dangerous in such a lake.

Measurements seem to show that the height of the water in the lake changes from year to year, but on the whole it is shrinking about one foot each year. Probably in only sixty years the lake will be completely dried up. This shrinkage is due to the fact that the water of the lake evaporates more rapidly than fresh water can flow in to take its place. Much water is now diverted from the rivers for irrigation, and this also decreases the inflow.

Outside of Salt Lake City there can be seen the old shores and cliffs of an ancient lake extending along the base of the mountain. A long time ago the climate of this country was much less dry than it is now, and great fresh water lakes occupied large portions of it. The largest of these ancient lakes has been named Lake Bonneville, and this once covered the site of the present Salt Lake City to a depth of eight hundred and fifty feet.

In the Dead Sea of Palestine, whose surface is thirteen hundred feet below sea level, the characteristics of a salt lake are even more pronounced. Its waters are even more salt than those of the Great Salt Lake, and its surrounding shores are desolate wastes of salt and sand.

THE SALTON BASIN.

Travelers who go to California by the Southern Pacific Railroad, after passing the town of Yuma, Arizona, crossing the Colorado River, and traveling some distance through a wide, sandy waste between two ridges of mountains, reach a little station called Salton. It is situated on the edge of a lake which is three hundred feet below the level of the sea, and the story of how this lake came to be made is most interesting.

Many centuries ago the Gulf of California stretched one hundred and fifty miles farther northward than it does now; at this time the turbulent Colorado River, after its passage through the wonderful canyon, poured its waters into the gulf above the town of Yuma. In the course of many centuries a great delta was built up which extended far out into the gulf and over which the river flowed. Gradually this delta cut off the upper end of the gulf and made of its northern extremity an inland lake. The waters of this new lake evaporated rapidly in the dry, hot air, and now all that is left of it is the little Salton Sea.

It is supposed that the river for a long time flowed into the gulf; then it overflowed, owing to a shifting of the channel, and filled the Salton Basin again, and thus it alternately changed the position of its mouth from the gulf to the basin many times. Much soil has thus been carried in to fill up the basin, and even now at high water in some years the river overflows its banks on its way from the Grand Canyon to the Gulf of California and materially raises the level of the Salton Sea.

HOW WATER SOMETIMES FORMS SPRINGS.

It is well known that springs of clear water can only be found in valleys, or at least that if they are on a hillside there is always some ground nearby which is higher up than they are. It is from this higher ground that the waters of the springs must always come. When the upper heights are covered with rain, a part of the water runs directly off to form streams and brooks and eventually to swell the volume of some river running to the sea, but another part always sinks into the ground. If the soil is clay rather than sand, and if its slope is steep and the rain a dashing one, most of the water will run off the surface into the streams. On the other hand, if it is a gentle slope and a sandy soil, a great deal of the water will sink into the ground to feed the springs, especially if the rain is a quiet one—for it takes time for the water to sink into the ground. The water descends until it strikes a harder layer of rock, along which it then flows down the slope of the hillside and at last comes to the surface in the form of a bubbling spring.

Quite frequently the spring is at some distance away from its source of supply, so that even in dry countries there are sometimes found these refreshing supplies of water. The water often travels a great distance into the ground before it comes to the surface again: it is estimated, however, that it can not go down into the earth more than five or six miles, for the pressure of the rocks above would at that depth close up all spaces through which it could flow.

Spring waters are generally clear and pure and carry very little surface sediment, but they may have dissolved away very much of the rocks and earths through which they have flowed. Yet springs and wells generally supply a better water than surface streams. There are many different kinds of springs: their waters may be hot or cold, they may have dissolved so much material in their passage underground that they are bitter to the taste and may be good for medicine, and the waters themselves may flow continuously or only at intervals when the supply on the higher grounds is not cut off.

If the water which comes from a higher elevation flows into a porous layer of rock, which lies between two harder layers and at last extends below a valley, it will be necessary in the lower country to bore through the upper and harder layer of rock to reach the center layer where the water is. When this has been done the water often spouts up to a considerable height on account of the pressure of the water that is above it. Such wells are called Artesian wells; they are found very useful in dry countries where surface springs are unknown.

SPRINGS WHOSE WATER IS HOT.

The eruption of both volcanoes and geysers is due to the explosive action of steam, and this shows us that their origin is far below the surface of the earth. An internal explosion may not be powerful enough to send rocks and ashes through the vent of a volcano, and yet it may be able to send a column of water high into the air through the pipe of a geyser. And a force not quite strong enough to lift a column of water and form a geyser, may produce a hot, or boiling spring.

So, like geysers, hot springs arise in regions where there has been some great disturbance of the earth, as for example in a volcanic region, or where the rocks have been folded to form a mountain chain. The surface waters may have been able first to penetrate to a great depth and then, after having been heated, they are forced up through the fissures in the rocks. Everywhere on the earth we would find that the interior was intensely hot, even only a few miles below the surface. At greater depths the heat is so great that the whole earth's interior would undoubtedly be a flowing, molten mass if it were not pressed solid by the enormous weight of the material above it. And so hot springs may be found among the ice of the Arctic regions, or on the slope of a snow clad mountain as well as in the warmer regions of the earth.

One of the most interesting things about this kind of springs is the enormous quantity of material which the hot water dissolves out of the rocks through which it passes and brings to the surface of the earth. It is estimated that the springs at Bath, England, with a temperature of about one hundred and twenty degrees, have in the last two thousand years brought enough material to the surface to build a mound four hundred and forty feet high and half a mile through at the base. This mound would be of almost exactly the same size as the volcanic mountain, Monte Nuovo on the bay of Naples.

The springs also liberate a great amount of heat from the earth's interior and so hasten its cooling. The temperature of the Carlsbad in Austria is one hundred and sixty-five degrees, and that of the Wiesbaden in Germany is one hundred and fifty-eight degrees. At Hot Springs, Arkansas, there are sixty hot springs which send out fifty thousand gallons of water each day, some of which is as hot as one hundred and fifty degrees. Many of the springs in Iceland are almost exactly as hot as boiling water.

In many parts of the world, and especially in the Yellowstone National Park, the hot springs have a great deal of lime dissolved in them, and this is deposited upon reaching the surface in beautiful formations. These consist of a series of basins or terraces, and the water falls in cascades from one basin to the next. The pink and white terraces of Rotamahana. New Zealand, were the most famous in the world until destroyed in 1886 by the eruption of the volcano Tarawera. The medicinal properties of some springs are due to the minerals which the waters have dissolved out of the underground rocks. The Saratoga springs of New York, the Sulphur springs of Virginia, the Iron and Soda springs of Colorado, the Hot springs of Arkansas, and the Vichy springs of France have been known for their medicinal virtues for many years.

GEYSERS, OR FOUNTAINS OF BOILING WATER.

In Costa Rica, Central America, there is found an extinct volcano called Poas, which has two craters. The one on the top of the mountain is filled with a beautiful sheet of blue, cold water, surrounded by a semi-tropical vegetation. One thousand feet below this there is the other deep crater with steep walls half a mile across, and which shows at its bottom a grayish colored pool that is the basin of a geyser. Every twelve or twenty minutes the smooth surface of the water is disturbed and a column of water and steam is sent into the air to a height of several thousand feet. At times ashes and volcanic dust are forced up with the water, so that the shrubs and trees near-by are covered with a beautiful, white powder.

Most geysers are not so clearly connected with volcanoes as the Great Geyser of Poas, but their action is so like a volcano that they are often called "hot-water volcanoes." The eruption of a geyser takes place because its pipe, or throat, becomes filled with water and this produces so great a pressure on the hot water lower down that this is prevented from boiling. By lowering a thermometer into the pipe of a geyser we can find how very hot this lower water sometimes is: a heat more than forty-eight degrees above the heat of boiling water is sometimes found in this way. At last, however, the upper water is evaporated, or perhaps it spills over the side of the basin, the pressure on the water below is relieved, and it suddenly bursts into steam and, exploding, shoots the upper water into the air. The pipe then fills again, and after a time there is another explosion and another spouting.

Some of the finest geysers send up their steam jets amid the ice of Iceland, most of them being in regions of recent volcanic activity. The Great Geyser rises from the basin-like center of a mound twenty feet high and about two hundred feet across. This mound has been formed of material which was slowly deposited by the cooling water. The center opening is about ten feet across and narrows as it goes down to a depth of seventy feet below the surface, where there is a bend in the pipe. Its volume of water is ejected to a full height of one hundred feet, rising gradually like a fountain and taking ten minutes for an eruption. From a study of the material which this geyser has deposited it is estimated that the geyser has been in eruption throughout the past three thousand years.

The Stroker, or the Churn, is another geyser in this same country which can be made to spout by pouring a load of dirt or sods down its throat. About twenty minutes after this has been done, with a rumbling and trembling of the ground, the black mass of boiling water, sods and steam shoots forth in a column about one hundred feet high and six feet through, and remains active until the foreign material has all been thrown out. The geysers of the Yellowstone National Park are equally famous. ''Old Faithful'' sends out a fountain of boiling water more than one hundred feet high once in every hour, and there are a great number of other, smaller geysers in the region.

HOW GREAT CAVES ARE MADE IN THE EARTH.

If you will take a glass of clear lime-water, that is, water in which lime has been dissolved, and breathe into it through a glass tube, you will see that the water will at once begin to grow of a milky-white color, but if you continue to breathe into the water it will soon become clear again. The milky appearance was made by a gas in your lungs called carbon dioxide, which combined with the lime in the water and made a very great number of little particles of the rock called limestone. But when you went on breathing, so much carbon dioxide got into the water that together they made an acid called carbonic acid, and this acid then dissolved the little particles of limestone again, so that the water then became clear. If next you should let the water evaporate, you would find that all the lime was left behind in the form of particles so small that they make up what seems to be merely a white powder.

This simple experiment shows how water can carry a rock which has been dissolved in it, and how it may transport it from the earth's interior and afterward deposit it again on the earth's surface. All the really large caves of the world are nothing but caverns made in limestone rock, where the underground waters containing carbon dioxide have dissolved the limestone away. After the water has dissolved the limestone away, it usually carries it to the earth's surface where it frequently deposits it. For example there is a spring in Westphalia that every year carries up enough limestone in that way to make a square block twenty-four feet on each edge, while another in Switzerland whose waters are warm is estimated to bring so much as sixty thousand cubic feet to the surface each year.

Thus the action of water is ever carving the earth's interior no less than its surface. Some of the finest caves of this type are found in Austria, while the Luray caverns of Virginia and the Mammoth Cave of Kentucky are probably the most famous in the world. The Mammoth Cave is more than eleven miles long, and consists of many large chambers connected by low passages. Some of these chambers are from seventy to eighty feet in height, while the largest of all, called the "Mammoth Dome," is from two hundred and fifty to three hundred feet high.

THE LURAY CAVERNS AND WHAT IS FOUND IN THEM.

We have learned how water can in the course of many ages carve out great caves in the earth, but not only does it make them, but it also decorates them in a marvelous fashion. Trickling through the crevices in the rocks above, it falls from the roof drop by drop, ever leaving behind a very little of the limestone which it has dissolved. And thus a little pendant, almost exactly like an icicle, begins to grow, each drop making it a very little larger or longer until at last it becomes a great, heavy, icicle-like mass of solid lime. This formation, growing slowly downward from the roof of the cave, is called a Stalactite. The water dropping from each stalactite to the floor of the cave will there build up in just the same way a pointed mass of limestone which is called a Stalagmite. Sometimes the stalagmite growing up from the floor gets so long that it meets the stalactite hanging from the roof, and then the two may unite and form a single column.

The Luray caverns in the Shenandoah Valley of Virginia, were discovered in 1878, and since then they have been visited by thousands of people. They cover about ten acres, and their lowest point is about one hundred and sixty feet below the surface of the ground. Although not as large as the wonderful Mammoth cave of Kentucky, with its remarkably large chambers, lakes, and its underground river, yet they excel all others in the extent, variety, and beauty of their formations.

In these caverns there is hardly a square yard that is not decorated. White, pink, blue and amber are some of the colors shown in these beautiful stony formations. One column is thirty-five feet high, of a rose color, and beautifully carved. Then there are the Cascades, which look like cataracts suddenly changed into amber colored marble. There are several sword-shaped stalactites, fifty feet long and from three to eight feet thick, which are hollow and when struck strongly by the hand give out the tones of tolling bells. In another part of the caves three white blankets hang side by side with several variegated ones; they are translucent and when lighted from behind show beautiful folds like a woven shawl. All over the caves the water can be seen still trickling down drop by drop, slowly building up new wonders, even now, as it has done in the many centuries of the past, and everywhere the clearest-lakes increase by their reflections the marvelous beauty of the strange structure around them.

THE PETRIFIED FORESTS OF ARIZONA.

We have seen how the great beds of coal tell us that at one time the climate of our world was quite different from what it is now, and how the luxuriant vegetation from which the coal beds were formed then covered a part of our country. At one time the climate of arid Arizona was quite moist and a great inland sea covered much of the State, on the shores of which tall evergreen trees were growing. These trees grew large, fell into the water, became ''water soaked'' and sank in great numbers to the bottom. In the course of time they decayed, but as this process was going on the minutest structure of their wood was replaced and its form preserved by becoming filled with mineral matter which had been dissolved in the water. When each little part of a plant or animal is thus replaced by hard mineral matter, we at last obtain a perfect image or form of the plant or animal, but this image is wholly made out of stone. It is so exactly of the same shape as the plant or animal which it has replaced that it is hard for us to realize as we look upon it that we are not looking at the animal or plant itself, but only at a sort of stone image of it. When such an image is formed we say that the plant or animal has become "Petrified."

In Arizona, at an elevation of fifty-seven hundred feet above our present sea, we may see fragments of petrified trees lying about in profusion over an area of eight square miles. In some cases the exposed log measures from fifty to two hundred feet in length and from three to five feet through, showing that the original trees must have been of immense size. The centers of the logs often contain beautiful quartz crystals and the broken fragments display all the colors of the rainbow. If a cross section of one of these trees is made and its surface is polished, beautiful rings and all other characteristics of the original wood can be seen.

The original layer of rock, in which the trees were buried during this wonderful transformation and from which they have fallen, is some seven hundred feet above their present position. A single tree, forming a beautiful, natural bridge may be seen spanning a canyon forty-five feet wide, and this is still lying in its original position.

In the Yellowstone there are also many wonderful petrified trees, but these are not as ancient as those of Arizona. But many of them are still standing erect just where they used to grow—a wonderful and most striking forest, which is made of trees of stone.

CHAPTER XXX.

Our Earth As a World.

THE GREAT SIZE OF THE WORLD.

IN nearly all that we said about our earth in the first chapters of this book, we spoke of it as a very little world. When we think of our wonderfully great sun and of the immense universe of other, even larger, suns, and even when we think about many of the other worlds which like our own are members of our sun's family, the planet on which we live does indeed seem very small. But we ourselves are very little creatures, and can see and comprehend so little that when we stand on our world and try to compare its size with the greatest things around us we are overwhelmed by what seems to us its enormous magnitude.

Sometimes as we stand before an enormous building or at the foot of some towering mountain, the great mass at which we are looking seems so very large and we in comparison seem so small that we are overcome by a feeling of depression; we feel that we are too small to grasp or comprehend the object that is before us. But how much more impossible it is for us to comprehend the great mass of our whole world! As we stand on the seashore, or at the edge of some level plain, we may think to ourselves how the sea or the plain is not really flat, as it seems to us to be, but how it really curves downward a very little in every direction, so that at the distance of a mile away it has curved downward about eight inches, and during the next mile it has bent downward eight inches more, and so on, and that if we walked straight on for twenty-four thousand miles this uniform, downward bending would have caused us to round the whole ball so that we would approach the level plain or the sea at the back of where we stood before.

But it is quite impossible for our little minds to grasp the enormous mass of earth included by this great circle. Although we can not do this, yet we can find just how large it really is, we can weigh it and find how it is forever turning around, and also discover many other interesting things about it. And we will tell how all these things are found out in this present chapter.

The earth is big in two ways, first with regard to its weight, and second with regard to its size. From Geography we have learned the names of many countries, oceans, long rivers, and high mountains, and some of us may have been on the ocean many days out of sight of land, and may have visited countries where the people speak an entirely different language from our own. Possibly we have traveled across the United States for five days and nights from the snows of winter to the sunshine and oranges of California, passing over three ranges of mountains, one of which lifts its head more than two miles above the level of the ocean from which we started. Earthquakes and restless volcanoes destroy large cities, and floods cover vast areas without touching our little habitation. All these things impress us with the immensity of our world, however much the telegraph and the electric cable may seem to have brought together the remotest corners of the earth.

To measure and weigh such a world, as it goes rolling and spinning around the sun, with its rough surface of land and its tossing waters, seems almost an impossibility. But men of various countries have been for a long while measuring and investigating the earth, and by combining these investigations with measures on the stars they have found out some things very exactly. They have proved that we are living on the outside of a rapidly turning ball, which is slightly flattened at the poles so that a person at the pole is thirteen and one-half miles nearer the earth's center than when he is at the equator. The distance through this ball at the equator is 7,920 miles. It is found to be quite heavy for its size; although it is very hot on the inside, it is a perfectly solid rock all the way to the center. It is covered with a protecting and life giving ocean of air which is at least one hundred miles high. We will now see in more detail how all these things have been found out.

HOW WE KNOW THAT THE EARTH IS TURNING AROUND.

We learned in the very early chapters of this book how the sun, moon and stars rise and set day after day. Now the sun is four hundred times as far away from us as the moon, and the stars are many times farther away than the sun, and yet they all move from east to west as if they were all at the same distance from the earth and all moving at just the same speed. Night after night the sky appears as if it were the inside of a vast, revolving dome with the constellations painted upon its inner surface. Is it not much more reasonable to suppose that our little earth is turning around while the heavens are at rest than to suppose that once in every twenty four hours the whole vast dome turns around our very little earth?

And so for many centuries men thought it very probable that our earth itself is turning. And afterward astronomers observed that certain things happen on the earth which show us with entire certainty that the earth is really turning around. One of these things is the following: If we ascend a high tower and drop a body from the top of it, we will see that the body does not strike the ground just at the base of the tower, but a short distance away toward the east. If the earth were not turning the body would fall straight down and strike the ground at the base of the tower. But if the earth is really turning then all points of its surface, from the tiniest snow crystal on the loftiest mountain to the smallest pebble at the bottom of the deepest ocean, are carried around the earth's axis once each day. But the snow crystal must travel faster around the earth's axis to make the circuit in the same time as the pebble because it is moving in a larger circle. And for the same reason the top of the tower must travel faster than the base, otherwise the tower would be torn to pieces.

Let us now see what happens to the falling stone. Simply because it is moving faster when on the top of the tower than when on the ground at the base of the tower, it will be thrown ahead on the ground, exactly as if you threw a ball from the window of a moving train it would not fall on the ground just opposite the point from which you threw it, but would be carried some distance ahead. This is because it was moving forward while it was being thrown. And so we find that the body dropped from the tower is carried forward too, a thing that can only be explained by supposing that the earth is turning. Astronomers after many trials under favorable conditions have performed this experiment with results which have convinced them that the earth is certainly turning from west to east. The best results have been obtained when a body has been dropped down a mine shaft. In a drop of five hundred feet the body falls away toward the east a distance of about one inch.

There is another very striking way of showing that the earth it turning, and by this way we can actually watch our great world turning around. A very heavy weight is hung by a very long, thin wire, and the weight set to swinging. It can be shown that the direction in which the weight swings will not be changed, even if the earth twists and turns or moves under it in any way whatever. This strange fact can be illustrated very beautifully by building up a little frame work on a table, hanging a weight from the frame, and setting it to swinging. If the table is pushed around or turned in any direction at all, the weight will nevertheless remain always swinging in exactly the same direction as at first. We see the table turned into different positions under the weight, which remains unaltered in the direction of its motion. And in exactly the same way we may see the earth actually turning under a much larger, swinging weight, and we can easily determine just how fast it is turning. From this very beautiful experiment, which has been performed many times, we can actually see that the earth is turning completely around once in exactly twenty-four hours.

HOW WE KNOW THAT THE EARTH IS A ROUND BALL.

That the sun is round is easily seen with the naked eye at the times of sunrise and sunset, and we know too that the full moon and all of the planets are of the same shape. Since the sun, moon and planets are all round it is perfectly natural to suppose that the earth is round too, but we can easily show that this is so in many different ways. Perhaps the clearest of these is the one which depends upon the observation of the North Star.

We have learned how there is a star called the North Star, or Polaris, which always shines out in the north a short distance above the ground, and which seems to stand still night after night throughout the year. But if we should walk southward over our great earth we would find that although the North Star stayed always fixed with respect to the other stars, it would sink ever lower and lower down toward the ground; and if we continued our journey all the way to the equator, we would find that from there it seemed to rest exactly on the ground. If we started back, it would appear to rise higher and higher again, until when we reached home we would see it quite high above the ground, exactly in its old position.

The North Star has risen higher and higher in the sky as we traveled northward from the equator. If we continued our journey it would continually rise still higher as we advanced and could we reach the North Pole of the earth we would there see it shining out exactly over our heads. As we traveled from the equator to the pole it has climbed steadily upward from the ground to the point exactly overhead. If the earth were flat, and not round, then as we took the same trip, we would find that at every point of our journey the infinitely distant North Star would appear at exactly the same height above the ground in the sky.

Standing on the shore, the waters of the ocean look rough and unwilling to yield any result. Yonder sailing vessel has just reached the line separating sky and water; soon its hull begins to disappear, then only the top of the mast can be seen, and at last the ship seems to sink down as if swallowed up by the sea. Again, out upon the light-house on the lonely island, the ships, from whatever direction they come, east or west, north or south, always appear gradually, the highest point of the vessel being seen first. This shows us that the surface of the water is curved away from the light-house in all directions.

Most of us have seen a sun dial, which is placed out-of-doors and shows the time of day by the shadow that is cast upon a numbered plate. Since the invention of the telegraph, even this simple device will prove to us that the earth is round. For if two sundials are set up, one in New York and the other in Chicago, and if there is at hand a telegraph key ready to signal to Chicago where someone is ready to receive the signal, and if this is sent on the instant when the shadow on the dial points to twelve, that is on the instant when the sun is exactly south of New York, then the observer in Chicago will not receive the signal at noon there. If at the instant he receives the notice of its being noon in New York he will look at his dial, he will find that the shadow points to about five minutes after eleven. If he should wait, and when the shadow of his dial indicates twelve o'clock, should send a signal to New York, it would be found that the dial there showed about five minutes before one.

Since the signal travels between the two dials in very much less than one second of time, we may rightly consider that practically the whole difference between the two times is caused by the roundness of the earth; were the earth flat, time by the sundial would be everywhere the same. By traveling from the equator to the pole we find that the earth curved in a north and south direction, and now we find that it curves in an east and west direction.

There are many other ways beside these of showing that the earth is a round ball. For example, in an earlier chapter, we told how when its shadow falls on the moon at the time of an eclipse it is always seen to be a round shadow. No constantly turning body could always cast a shadow that is perfectly round unless it were itself a round body. And so, strange and impossible as the idea at first seemed to men, we are perfectly sure that the earth on which we live is a great, round, turning sphere.

HOW AN OCEAN OF AIR ALWAYS RESTS ON OUR TURNING EARTH.

The rapid turning of this great, round world has been a puzzle to many minds both young and old. When traveling in a fast express train, unless you look out a window or the train slows down or stops, you do not feel that you are going almost a mile a minute along a track. The earth does not slow down nor stop, and there are no signs on the earth or in the air to tell us of our motion. Near the equator there are the trade winds always flowing in a definite direction, but these signs of the earth's turning are not visible to all of us.

Just as the fish move about and pass their lives in a sea of water, so man lives and does his work in an ocean of air which is held around the earth and turns with it, just as the houses, and trees and mountains do. The ocean of air is far deeper than the ocean of water, and while the fish, some of them, have the freedom of the ocean nearly from the top to the bottom, man is ever compelled to remain at the very bottom of the great air-ocean. Sometimes, by ascending high mountains or by means of a balloon, he may explore a short way from the bottom, but he can never mount anywhere near its upper surface.

It is believed that our air-ocean is at least one hundred miles deep, for shooting stars from outside space have been observed to flash into it at that height. The sunlight is scattered in all directions as it passes through it, and thus is produced the diffuse illumination of the daylight sky. Some of the rays however come straight through to heat the earth; we have seen how the air holds in this heat, and that if it did not do so the earth would become intensely cold at night, even in summer time. There are high mountains whose tops are not protected by so deep a covering of air as most lands are, and there we find snow the whole year around, even in the tropics. The twinkling of the stars, twilight, and many other interesting phenomena are due to the fact that the waves of light from the heavenly bodies must pass through many miles of our air before they reach our eyes.

We may wonder why, if the earth turns so rapidly, the air is not stirred up, just as it is when an express train goes speeding by; for the point on the earth where we are standing may be going fourteen times as fast as the fastest express train. The reason is simply because the earth turns so very steadily. The great ocean of air is held down by the earth's pull, and it and everything upon our earth all turn together. All goes on so smoothly and steadily that although we are being ceaselessly whirled around it is only by most careful and ingenious experiments that we can detect that we are moving at all.

HOW MEN MEASURE THE SIZE OF THE EARTH.

To measure the size of the earth directly as we would measure a piece of cloth with a yard-stick would be an almost impossible undertaking, especially as three fourths of our world is covered with water. Indeed if the earth were not a round ball, the task would be an almost hopeless one. Even in the very earliest times men thought of the distance around any circle being divided into three hundred and sixty equal, little, curved parts and they called one of these little parts a Degree, so that every circle whether it be large or small contains exactly three hundred and sixty degrees in the curved line which bounds it. Now if in any way we can measure how many miles long one degree on the round earth is, we will only have to multiply this length by three hundred and sixty and so we will get the distance all the way around the earth.

The earth is so large that even one degree is too long to be measured directly by a yard-stick, so astronomers do it indirectly but more accurately by means of triangles. They first select a very large number of stations in the country which they are to measure, and they imagine a great number of straight lines to be drawn joining the stations together. The lines joining any three stations thus make a great triangle on the ground, and they next set up very fine instruments at the stations and measure all the angles of these triangles. Sometimes they build high towers over the stations so that they can see one from another, for the stations may be fifty miles apart, or even more.

By measuring all the angles in this way the shape of each triangle is learned, and as soon as this is known we can, if we wish, draw a very accurate picture of each successive triangle on paper and so get a map of all the country over which the triangles lie.

But so far we do not know the "scale" of our map, that is we do not know how many miles long any one of the lines on it is. To get this it is only necessary to measure any one line on the earth with the very utmost care; if we found that this line was ten miles long, and if the same line on our map was twenty inches long then we would know that every inch on the map corresponded to just one half a mile on the earth. And as all the parts of our map are in just the same proportion as the much larger figures on the earth, that is as our map is only a very exact little picture of a part of the earth itself, to find the distance between any two of the stations in miles it would only be necessary to measure this distance on the map in inches and to divide the number of inches which we got by two. If, for example, the distance from New York to Albany was two hundred and seventy-six inches on the map, then the real distance between them would be one half of two hundred and seventy-six, or one hundred and thirty-eight miles.

Suppose that in the way we have just described we have found that New York is exactly one hundred and thirty-eight miles south of Albany. We must next find how many degrees of our round earth there are between these two places, and this we do by observing the stars. If there was a star which passed exactly overhead at Albany, we would find it did not lie exactly overhead in New York; from here it would be seen to be about two degrees north of the overhead point; that is, it would be about as far from the overhead point at New York as four times the distance across the full moon. That is, in walking from Albany to New York we would move our overhead point two degrees along the celestial sphere, and this shows us that the one hundred and thirty-eight miles which separate Albany from New York are the same as two degrees on the earth. And therefore one degree on the earth is the same as sixty nine miles; and three hundred and sixty degrees on the earth, which is the number of degrees around the whole earth, will be three hundred and sixty times sixty-nine miles. And in this way it is found that the distance around our world is a little less than twenty-five thousand miles.

HOW WE MEASURE TIME.

Suppose that at the instant when the sun was exactly south of you a clock was set to show exactly noon, and then started to running. If for several days you noted the exact time when the sun again got exactly south, you would find that if the clock is neither running slow nor fast, the days from sun noon to sun noon are not all of the same length. These days, which are the same as the days indicated by a sun dial, are of unequal length because the sun as we see it seem to move eastward among the stars, does not move with a uniform speed. Sometimes we are nearer to the sun than usual and then it seems to move fastest, and when our earth is farthest away it seems to move most slowly. Our clocks and watches are constructed to keep time by an imaginary sun which is thought of as moving around the celestial sphere among the stars with a uniform speed. Sometimes this imaginary sun is behind the real sun and sometimes ahead of it, so that sometimes the time shown by our clocks is as much as fifteen minutes faster than the time shown by the real sun as it shines on a sun dial.

If the earth were flat, then all the clocks would keep time together and would all show noon at the same instant. But we know that this is not so. At places east of us the clocks show afternoon when it is noon with us, and at places west of us the clocks show that there it is not yet noon. Each place has its own local time. Until recently each city kept its own time, and this was a great inconvenience in traveling. In 1883 the United States was divided into five "Belts," each about fifteen degrees wide, called the Colonial, the Eastern, the Central, the Mountain, and the Pacific.

As you pass from one belt to the next, a distance of about seven hundred and fifty miles, the time differs by one hour, the minutes and seconds remaining the same. So that all clocks if they differ, differ in the hour only. Thus in taking a trip to California by a central route, we enter the Central belt at Pittsburg, the Mountain belt at Ellis, Kansas, and the Pacific belt at Ogden, Utah. The various observatories of the country, like the Naval Observatory, at Washington, the Mare Island and the Lick Observatories of California, keep our clocks regulated to this Standard time by sending out a noon signal each day by telegraph.

HOW MEN FIND THE POSITION OF A SHIP AT SEA.

Now that we have learned about what time is, we are ready to understand how a sailor, even if he has been sailing alone for days on a trackless ocean, can find the exact position of his ship at sea. In the first place, he must have on board a very accurate clock, looking somewhat like a very large watch, and which is called a chronometer. This is always keeping Greenwich time. But we have seen that if he goes fifteen degrees, or about seven hundred and fifty miles, west of Greenwich the time at his ship will be one hour earlier than Greenwich time, and that if he is twice as far west it will be two hours earlier, and so on. And so it is only necessary for him in some way to find the time of day at the place where his ship happens to be; by comparing this with the time which his chronometer shows he will at once see the difference between his time and the time at Greenwich, and from this he finds how far east or west of Greenwich he is.

If he could look at a sun dial, its shadow would tell him at once the time of day at the ship, but it is, of course, not possible to mount a sun dial on a moving, rolling ship. Instead of this, he goes out on deck and measures the angular distance from the sun in the sky to the distant ring of water in which the sky and ocean seem to meet. For this he uses a very beautiful instrument called a Sextant, which is so small that it can be held in one hand. We know how the sun rises above the ocean and climbs higher and higher in the sky until noon, and how it then begins to sink again. And so when he has measured its height above the sea at any time, he can find by a short computation how long it will be before the sun will be exactly south, that is he can find what the time of day was when the sun had the height which he measured. For example, he might find that the sun was one fourth of the way to the overhead point when he measured it, and he might next find from his computation that three hours after getting this high it would get due south. Then he would know that at the instant he measured the sun it was three hours before noon, that is that it was nine o'clock in the morning. To this sun time he would have to apply the difference between the sun time and uniform clock time, which is given in a book for every day of the year, and so he would get the real ship time at the instant when he made the measure. If the Greenwich time that his chronometer showed was one hour faster than this, then he would know that he was exactly fifteen degrees, or one twenty-fourth of the way around the earth, west of Greenwich.

And by measuring the height of the sun above the sea at noon, or the height of the North Star, he could also find exactly how far his ship is north or south of the equator. And thus, even though he may have been sailing for days or even weeks, and though he may have seen nothing but one wide expanse of water in all that time, yet he can open his chart or map and make one little dot upon it and say, "It is exactly here at this point on the great world that I know my little ship is at this instant sailing."

HOW MEN FIND HOW MUCH THE EARTH WEIGHS.

Suppose that we suspend any heavy body, like a piece of lead, by a string from a nail driven into a post, and that we pull the lead to one side and then let it go. It will start to swing back and forth, and we will have what is called a Pendulum. The same pull that would make the lead drop to the earth if the string were to break keeps it swinging from the nail. In the course of time the pendulum will come to rest and we will have what is called a Plumb Line, which carpenters and builders find so useful, and which points downward toward the center of the earth.

If we hang such a plumb line on the south side of a mountain, then instead of hanging so that it points exactly to the center of the earth it will be pulled aside a very little by the attraction of the mountain upon it. In just the same way a tack hung upon the end of a string would be pulled to one side by the attraction of a magnet if this were brought near it. And if the plump line is hung on the north side of the mountain, it will be pulled a little southward by the attraction of the mountain in just the same way. If instead of using the plumb line, we fill a glass half full of water, and tilt it, the water will always come to rest at right angles to the plumb line, or "level," as we say. But if we hold the glass near the mountain, the edge of the water surface toward the mountain will be tilted up a very little way by the pull of the mountain upon it. Any other liquid may be used instead of water; the very fine astronomical instruments have little tubes upon them which contain a liquid called ether.

The weight on the plumb line is pulled straight down by the attraction of the earth, but it is also pulled slightly sidewise by the pull of the mountain. Were the mountain twice as heavy, it would be pulled sidewise twice as much; if the earth were twice as heavy as it is, the pull downward would be twice as strong as it is—that is the ball would weight twice as much as before—and the mountain could only pull it sidewise one half as much as it was seen to do. And similarly, the tilting up of the ether in the tubes of our instruments would be twice as great or one-half as great in the two cases as we actually see it. From these considerations, we can find how much stronger the pull of the earth is than the pull of the mountain and we can therefore determine how much heavier than the mountain the whole earth is. When we have found this, we then carefully bore deep holes all through the mountain and so find exactly what it is made of and how many tons it weighs. And thus, as we know how many mountains it would take to balance the earth, we learn the actual weight of the earth itself in tons. The mass is so large that we can not comprehend it; it is no less than six thousand millions of millions of millions of tons. That is to say, the earth is heavier than if it were made entirely of granite or marble, but lighter than if it were made of iron. Its weight is usually expressed by saying that our world is five and one-half times as heavy as an equally large ball made entirely of water.

WHY THE EARTH IS SO MUCH HEAVIER THAN WATER.

Anyone who has carried a pail full of water finds it necessary to rest or change hands often if he has to carry it far. If it had been filled with any of the ordinary rocks that make up the outer part of our earth it would have been three or four times as heavy as when it was filled with water. Now we have seen that the earth as a whole is nearly twice as heavy as this. What then is it that makes the earth so heavy that it weighs five and one-half times as much as it would do if it were made of water?

The true explanation is very simple. Suppose it were possible for you by some powerful force to press down the pail full of stones so that it would hold twice as many, just as we can pack down dry snow; it would then weigh six or eight times as much as it did when filled with water. Yet to compress hard rocks which we can hardly break with a hammer requires a very great force. To see clearly where this great force comes from, let us imagine that we have drawn on the ground a square which is one yard on each side. Upon every square inch of this the air is resting with a weight of fifteen pounds. Next suppose we go one yard below the surface and draw a square immediately under the first one; then upon this square there rests not only the air, but a cubic yard of earth besides. If we go down another yard and draw another square, the air and two cubic yards of earth will rest upon this, and so on: by the time we reach the earth's center, eight thousand miles below the surface, we can easily understand that the pressure will become enormous. Under such a pressure the rocks at the interior of the earth are very greatly compressed and made many times as heavy as the same rocks would be if they were on the surface. It is probable that the rocks near the earth's center are at least as heavy as if they were made of lead.

Men used to think that we are living on a thin shell of rock and that the whole inside of the earth is a molten mass, but we know now that is not at all so. Not only are we sure that such an enormous weight pressing even upon a molten mass would squeeze it together so hard that it would become solid, but from very many other things we know that our whole round earth is one solid rock. For instance, earthquakes produce waves which travel like sound waves in all directions and scientists find these waves recorded on their delicate instruments after they have traveled a very long distance or even entirely through and around the earth itself. These instruments tell us whenever an earthquake has happened and also how long its waves have been traveling. It is found that these waves travel very fast; if the interior were in a molten condition we know that they could not travel so far or so fast as they are seen to do.

Not only do we find in this and other ways that the earth is entirely solid but we can even learn exactly how solid it is. It is in fact found that the whole earth is a little more rigid than if it were made of steel. And so we see why the earth is five and one-half times as heavy as water, even though the material near its surface is only two or three times as heavy.

THE INSIDE OF THE EARTH.

We have now learned many interesting things about the outside of our great world, but what is it like on the inside ? The boiling geysers of the Yellowstone, the very hot lavas of Vesuvius, and the many hot-springs of the north and south that flow all the year around show us clearly that a part of its interior at least must be very hot. It has been found out that we have to bore down only about one hundred feet below the earth's surface to find a region where the temperature is constant. All over the face of the earth, in the tropics as well as in the polar regions, in winter and in summer, only one hundred feet below the earth's surface there is but one season, with a temperature of fifty-two degrees above zero.

We see that the heat of our sun which causes our winter and summer does not get far inside of our earth. Below this one hundred feet the temperature increases about one degree for every fifty or sixty feet we go down. A hole more than a mile deep was bored in Germany, and when a thermometer was lowered to the bottom of this wonderfully deep hole it showed that it was eighty degrees warmer there than at the top. At this rate of increase we would not have to go many miles below the earth's surface before we came to a region so very hot that all the rocks of the earth would be melted.

We know that at one time the entire earth was in a molten condition. At first it cooled off quite rapidly and became crusted over. For many, many centuries the cooling has continued, but it has by no means lost

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all of its great heat yet. All of the enormously great heat of its interior is that which has remained from the early times in which our earth was forming; the deep layer of rock above this inner, heated ball protects it as with an enormous blanket and keeps it from cooling rapidly. Yet, hot as it still is, this whole inner mass is solid. If the enormously great weight which rests upon it could be removed, there can be little doubt that this deep rock would at once expand and become a molten fluid, if indeed it would not in part change into a gaseous condition.

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